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Federation Affairs

Sewage Works Operating and Cost Records

INTRODUCTORY STATEMENT BY C. A. EMERSON, JR.

Chairman, Board of Control

Too frequently operators and officials in charge of sewage works fail to recognize the value of full and accurate records of the performance of sewage treatment works and feel that if the effluent appears satisfactory or if sludge can be drawn and dried without causing nuisance, the daily log and weekly report sheets are simply time-consuming inventions of little use to anyone. The true worth of such records oftentimes is not appreciated until something goes wrong and inquiry is made as to when and under what conditions the drop in efficiency of the plant was first noticeable.

When sewage flow approaches the capacity of the works, a properly planned and faithfully kept set of operating records will assist the designing engineer in determining just which portions of the works require enlargement or replacement, and may well be the means of saving investment of many thousands of dollars in structures which would not correct the particular shortcomings of the existing plant.

Much can be learned by comparing cost of operation and results secured at different plants, but such comparisons cannot be easily made or have full value unless operating records follow a uniform system and are in sufficient detail to make certain that underlying conditions of the two plants are comparable.

Believing that the Federation of Sewage Works Associations is the logical organization for development of a standard system for record keeping and cost accounting for sewage treatment works, the Board of Control authorized appointment of a committee to study the needs of plants of various types and to investigate methods in use throughout the country, in order to make recommendations covering a basic system which would meet the requirements of works of the generally prevailing types, and which could be modified or elaborated to meet special conditions.

This committee has worked faithfully and its report merits careful study. Particular attention is called to the recommendations concerning adoption of standard units of measure for expressing results. Manifestly this is of much importance, and will facilitate comparisons of performance of different plants.

While it is quite possible that extended discussion and trial may justify

changes in some details, the general principles set forth in the report seem logical and should be given a thorough test.

The secretaries of the local associations are asked to provide room in their programs for discussion of this report, so that ultimately the Federation may hope to set up standard procedure for reports, which will represent the consensus of opinion of the vast majority of workers in the broad field of sewage treatment.

Report of Sewage Works Operating and Cost Records

MR. C. A. EMERSON, JR., *Chairman,* Dec. 2, 1931
Federation of Sewage Works Associations,
Pennsylvania Building,
Philadelphia, Pennsylvania.

DEAR SIR:

In accordance with your written instructions of November 12, 1929, the Committee has prepared a report on "Sewage Works Operating and Cost Records."

In preparing the report the work was divided among the following sub-committees:

1. Operating Records
   C. K. Calvert, *Sub-Chairman*
   Wellington Donaldson
   W. S. Mahlie
2. Fixed Costs
   Morris M. Cohn, *Sub-Chairman*
   Charles R. Cox
   G. J. Requardt
3. Operation and Maintenance Costs
   C. E. Keefer, *Sub-Chairman*
   E. G. McConnell
   Gus H. Radebaugh

One of the purposes of the report has been to standardize the records that it seems desirable to obtain at sewage works, and to have these records in such a form that performance and cost data at different plants can be compared.

Respectfully submitted,

C. E. KEEFER, *Chairman*
C. K. CALVERT
MORRIS M. COHN

Introduction

The rôle played by sewage works in protecting streams and water courses is one of increasing importance. The great advances made during the past decade in the art of sewage treatment, coupled with the growing demand on the part of the public for waterways that can be used for recreational purposes and can serve as suitable sources of water supply, have increased the importance of sewage works, and have emphasized the need of a trained personnel, capable of operating these works with a high degree of skill and efficiency.

One of the important details of operation consists of keeping accurate and complete records of the performance of the works. These records should be concise, but at the same time they should be sufficiently complete to include all of the important facts relating to the operation of the plant. At the present time there is a lack of uniformity in keeping such records, with the result that data collected at one sewage works frequently cannot be compared with data obtained at another plant. In order to improve this condition this report has been prepared, outlining the operating data to be recorded, the practical control tests and the analysis of the raw and treated sewage to be made, and the method to be followed in keeping operation and maintenance costs.

Annual Reports

An annual report should be prepared and kept on file for future reference at all sewage works except the very smallest. This report should contain all of the items of importance pertaining to the operation of the plant. If possible, the report should be printed for distribution, especially where the sewage works is large or the type of plant is unique.

In those cases where the reports are printed, it is recommended that the following descriptive information regarding the sewage works, as outlined in Schedule I, be included so that the operating data will be more intelligible to those readers who do not have first-hand information about the works.

Schedule I. Descriptive Information Regarding Sewage Works

1. List of treatment processes in sequence of sewage flow, such as bar screens, type of fine screens, grit chambers, Imhoff tanks, type of mechanically cleaned settling tanks, sprinkling or contact filters, aeration, intermittent sand filters, type of mechanical filters, final settling tanks, chlorination, etc.
2. List of accessory processes such as separate sludge digesters, open sludge beds, glass covered sludge beds, sludge lagoons, compost tanks, incinerators, sludge filters and other drying equipment, etc.
3. Date operation started; date and nature of subsequent additions.
4. Design basis of sewage works as to volume of sewage to be treated and population to be served.
5. Estimated population served.

6. Separate or combined sewers.

7. Storm water diversion outlets, bypasses or other arrangements of the sewerage system which affect the sewage works loading or population rating. State the number of days such devices are in operation or the quantity of sewage diverted from the sewage works.

8. Nature and quantity of industrial wastes, if any, affecting markedly the character of the sewage or creating special treatment problems.

9. Method of measuring sewage flow whether by recording meters or other devices.

10. Purposes of sewage treatment, whether abatement of local nuisances, protection of water supply, bathing or shell-fish areas.

Operating Data and Practical Control Tests

In spite of the fact that there are many sewage treatment works in this country there is a great lack of reliable data on the operation of these plants. Furthermore, there is a good deal of confusion due to the lack of agreement as to the essential data and the form in which they should be presented. With this thought in mind Schedules II and III have been prepared to serve as a guide in collecting the essential operating data at sewage works.

Schedule II indicates the information that should be obtained, the units of measurement to be used in recording quantities and the frequency with which the data should be collected. It is especially desirable that the same units of measurement or quantities be generally used throughout the country so that plant performances can be readily compared. For example; it is disadvantageous for one sewage works to report the quantity of raw sludge collected in gallons and for another works to report it in cubic yards. It is believed that all of the data included in Schedule II can be obtained by the operator of average intelligence without technical training, provided proper report forms are available and preliminary instructions are given as to their use.

It is recognized that many sewage works do not have the necessary trained personnel to make involved computations. Such being the case, those quantity units which involve the least calculation on the part of the operator have been recommended. Moreover the same units of measurement, where possible, are advised. For instance, it is recommended that the quantity of grit, screenings and all kinds of sludge (except heat-dried activated sludge sold as fertilizer) be reported in cubic feet.

An attempt has been made in Schedules I and II to list the minimum data to be obtained from each of the usual treatment processes. Individual preferences and local conditions, however, will determine how each of the recommended items may best be combined in daily, weekly or monthly reports as desired. In addition to the information to be obtained as listed in Schedules I and II, a daily record should be kept of the details of operation, such as the treatment units in service, sludge transfers, interruption in the treatment process, repairs, etc.

SCHEDULE II. OPERATING DATA AND PRACTICAL CONTROL TESTS

(Omit Those Sections Not Applicable to Local Conditions)

I. General Data

	Unit of Measurement	Frequency of Reporting
(Applicable to all types of treatment)		
1. Sewage flow:		
a. Total	M. G. D.*	Daily
b. Maximum rate	M. G. D.*	Daily
c. Minimum rate	M. G. D.*	Daily
2. Outdoor air temperature:		
a. Maximum	° Fahr.	Daily
b. Minimum	° Fahr.	Daily
3. Raw sewage temperature	° Fahr.	Daily
4. Weather, fair or cloudy	...	Daily
5. Precipitation:		
a. Rainfall	Inches	Daily
b. Snowfall	Equivalent inches of water	Daily
6. Electric power used	Kw. hr.	Weekly or monthly
Subdivide into the following items if possible		
(*a*) Pumping: Sewage Sludge		
(*b*) Mechanical equipment in settling tanks		
(*c*) Mechanical equipment in sludge tanks		
(*d*) Air compressors		
(*e*) Auxiliary equipment		
(*f*) Heating		
(*g*) Lighting		

*Except for flows less than 1 M. G. D., in which case the rate of flows shall be expressed in "thousand gallons daily." In no case are more than three significant figures justified.

II. Grit Chambers

1. Volume of grit	Cu. ft.	Daily
2. Average weight of wet grit	Lb. per cu. ft.	Weekly
3. Frequency of cleaning		
4. Method of grit disposal		

III. Grease Removal

(If separate from VI-5 and in addition to it)		
1. Type of skimmer		
2. Volume of skimmings	Cu. ft.	Daily
3. Average weight of skimmings	Lb. per cu. ft.	Weekly
4. Method of disposal of skimmings		

	Unit of Measurement	Frequency of Reporting
IV. Coarse Screens		
1. Clear opening between bars	Inches	
2. Volume of screenings	Cu. ft.	Daily
3. Average weight of wet screenings	Lb. per cu. ft.	Weekly
4. Method of disposal of screenings		
V. Fine Screens		
1. Clear opening	Inches	
2. Volume of screenings	Cu. ft.	Daily
3. Average weight of wet screenings	Lb. per cu. ft.	Weekly
4. Method of disposal of screenings		
VI. Primary Sedimentation		
1. Detention period, based on actual sewage flow	Hours	Daily
2. Frequency of cleaning		
3. Settleable solids, influent	Cc. per liter after 2 hrs.	Daily
4. Settleable solids, effluent	Cc. per liter after 2 hrs.	Daily
5. Scum removal	Cu. ft.	Daily
VII. Trickling Filters		
1. Depth of filter media	Feet	
2. Size of filter media	Inches	
3. Area in actual service	Acres	
4. Settleable solids, effluent	Cc. per liter after 2 hrs.	Daily
5. Relative stability, effluent	Per cent	Daily
6. Number of nozzles cleaned		Daily
7. Estimated area of pooling	Per cent	Weekly
VIII. Contact Beds		
1. Depth of bed	Feet	
2. Size of media	Inches	
3. Area in actual service	Acres	Daily
4. Settleable solids, effluent	Cc. per liter after 2 hrs.	Daily
5. Relative stability, effluent	Per cent	Daily
IX. Secondary Sedimentation (Following trickling filters or contact beds)		
1. Detention period, based on actual sewage flow	Hours	Daily
2. Frequency of cleaning		
3. Settleable solids, effluent	Cc. per liter after 2 hrs.	Daily
4. Relative stability, effluent	Per cent	Daily
5. Scum removal	Cu. ft.	Daily

	Unit of Measurement	Frequency of Reporting
X. Intermittent Sand Filters		
1. Area in actual service	Acres	Daily
2. Relative stability, effluent	Per cent	Daily
XI. Chlorination		
1. Point of application		
2. Chlorine applied, average	P. p. m.	Daily
3. Residual chlorine	P. p. m.	3 times daily
4. Actual contact period before test	Minutes or hours	Daily
XII. Activated Sludge		
1. Aeration period based on net sewage flow plus returned sludge Aeration period (hours) $= \frac{V \times 24}{S + R}$ Where V = volume of aeration tank in gallons S = sewage flow in gallons per day R = sludge return in gallons per day	Hours	Daily
2. Air used per gallon net sewage flow	Cu. ft.	Daily
3. Sludge return:		
(*a*) Total	1000 gals.	Daily
(*b*) Per cent of net sewage flow	Per cent	Daily
4. Mixed liquor, volume settled in $^1/_2$ hr.	Per cent	
5. Mixed liquor, dry solids by weight	Per cent	Daily
6. Dry solids in returned sludge by weight	Per cent	Daily
7. Sedimentation period, based on sewage flow plus returned sludge	Hours	
8. Sedimentation rate, based on sewage flow plus returned sludge	Gal. per sq. ft. per day	
9. Air pressure at compressor discharge	In. of mercury	
XIII. Sludge Digestion		
1. Tank volume actually used for digestion	Cu. ft.	
2. Temperature of digestion	° Fahr.	Weekly
3. Reaction at surface of sludge	pH	Weekly
4. Kind of chemical used to aid digestion		
5. Amount of chemical used	Pounds	
6. Volume of heating water	1000 gals.	Daily
7. Temperature of heating water to digester	° Fahr.	Daily
8. Temperature of heating water from digester	° Fahr.	Daily

	Unit of Measurement	Frequency of Reporting
9. Scum removed from digester	Cu. ft.	Daily
10. Sludge liquor:		
(*a*) Volume discharge from digester	Cu. ft.	Daily
(*b*) Method of disposal		
(*c*) Dry solids	Per cent	Daily
Note: See Schedule III for sludge quantities, characteristics and disposal.		
XIV. Sludge Drying		
1. Area of uncovered beds in use	Sq. ft.	
2. Area of covered beds in use	Sq. ft.	
3. Depth of wet sludge applied to beds	Inches	
4. Time sludge remains on beds	Days	
5. Area of mechanical filter in use	Sq. ft.	
6. Chemical used to condition sludge:		
(*a*) Per 1000 gals.	Pounds	
(*b*) Per ton of dry solids	Pounds	
Note: See Schedule III for sludge quantitites, characteristics and disposal.		
XV. Gas Collection		
1. Volume of gas produced	1000 cu. ft.	Daily
2. CH_4 content of gas	Per cent	Weekly
3. Gas pressure at meter	Inches	Daily
4. Uses made of gas		
5. Volume of gas used	1000 cu. ft.	Daily

Schedule III indicates the records that should be kept relative to the characteristics and quantities of sludge that are treated and disposed of. Regarding the percentage of dry and volatile solids, together with the reaction of the sludge, little time and skill are needed to make these tests. These determinations should be made at all except the smallest sewage works.

SCHEDULE III. SLUDGE QUANTITIES, CHARACTERISTICS AND DISPOSAL

(To Be Reported Daily Where Possible and Summarized Yearly)

		Solids			
	Quantity	Dry Per Cent	Volatile Per Cent	Reaction pH	Method of Disposal
Primary (except Imhoff tanks)	Cu. ft.	x	x		x
Secondary (except Imhoff tanks)	Cu. ft.	x	x		x
Digested (wet)	Cu. ft.	x	x	x	x
Digested (air dried)	Cu. ft.	x	x		x
Excess activated (wet)	Gal.	x	x	x	x
Filter feed	Gal.	x	x	x	x
Excess activated (filter cake)	Cu. ft.	x	x		x
Excess activated (final)	Lb.	x	x		x

Note: "x" indicates records to be made.

Analyses of Raw and Treated Sewage

Sewage works operators should endeavor to reach some general agreement as to the chemical and biological analyses to be made of raw and treated sewage. The purpose of reaching such an agreement is to find a common basis for comparing the efficiencies of the largest possible number of sewage plants. In order to reach such an agreement Schedule IV has been prepared. This schedule of analyses has been divided into two parts. In the first part is listed the analyses that should be required, and in the second are found the optional analyses that may be made at the discretion of the sewage works operator. The required analyses are recommended with the full appreciation that they will not include all the necessary determinations in every case. It is believed that these analyses should be made at every sewage works regardless of the special problems at any particular plant. It is recognized, however, that these tests require special equipment and the services of a trained personnel, and in the case of small plants they will frequently have to be omitted. For comparison with foreign practice, Appendices I and II present, respectively, the analyses made at the English and German sewage works.

Special problems that will require investigation will arise from time to time at numerous sewage works. At such times supplementary data not included in these recommendations will have to be collected. Furthermore, where research work is done, analyses of an unusual nature and not generally conducted will be required.

Regarding the adoption of a standard report form that would be suitable for all types of sewage works, it is believed to be unwise to recommend the adoption of such a form at this time.

All sewage and sludge analyses should be made in accordance with the latest edition of "Standard Methods of Water Analyses," published by the American Public Health Association.

SCHEDULE IV. ANALYSES OF RAW AND TREATED SEWAGE

(Results to Be Reported in Parts per Million by Weight)

I. **Required Analyses**

To be made on (*a*) Raw or Screened (state which), (*b*) Clarified and (*c*) Biologically Treated Sewage (listed in the order of probable importance with the more important first)

1. Five-day Biochemical Oxygen Demand (determined at 20° C.)
2. Suspended solids
3. Total solids
4. *B. coli* (completed). If sterilization is practised and in connection with stream or lake investigation

II. **Optional Analyses**

(Not listed in order of importance)

1. Suspended solids, volatile

2. Total solids, volatile
3. Oxygen consumed—especially in connection with stream or lake examinations or industrial waste problems
4. Total organic nitrogen—especially in sludges before and after digestion
5. Ammonia nitrogen—especially in effluents from biological sewage works
6. Nitrite nitrogen—especially in effluents from biological sewage works
7. Nitrate nitrogen—especially in effluents from biological sewage works
8. pH—especially on stale sewage and industrial wastes
9. Dissolved oxygen—especially in effluents from biological sewage works and streams or lakes in the diluting waters
10. Bacteria per cc. at 37° C.—especially after chlorination and in diluting waters
11. Plankton—especially in the diluting water
12. Alkalinity
13. Chlorides
14. Grease

It is recommended that laboratory examinations be made on samples collected hourly and composited on the basis of the volume of sewage flow during each 24-hr. period. The examination of samples at the time of peak load is important.

If analyses are based on any other than the 24-hr. composite sample, the time and method of collection should be stated. In those cases where samples are collected only during portions of the day, care should be taken to obtain representative samples. It will be necessary to stagger the sampling schedule so that influents to and effluents from various treatment devices represent, so far as possible, the same sewage. This result can best be obtained by allowing for the detention period in the treatment units. The method of preserving the composite samples should be indicated.

Cost Keeping at Sewage Works

An accurate knowledge of the cost of operating sewage works is of great importance. More attention should be given to the keeping of cost records than has been the case in the past. Such cost data, when known to be accurate, are of great value as they afford a means of comparing the costs of the same or different methods of sewage treatment in different localities. Furthermore, the sewage works operator is enabled to predict future costs by basing them on past records. With detailed costs available, the works operator can see what the major expenditures are, and he is thus better enabled to effect economies. Moreover, the engineer who frequently has to recommend a new type of treatment at an existing works will be greatly aided if accurate operating and maintenance costs of the old works are available for comparison with the estimated cost of operating the proposed plant. It is essential for comparative purposes that some uniform procedure of cost keeping be adopted. Careful consideration

has been given to the problem so that a single, standardized procedure might be followed.

The various expenditures involved in the operation and maintenance of a sewage works can be grouped under (1) fixed charges and (2) operation and maintenance charges.

Fixed Charges

Very frequently fixed charges are not included in the cost of operating sewage works, although these charges are a major item in the actual total cost of the disposal of sewage. The fixed charges include two items: (1) interest on the capital account or investment and (2) depreciation of the capital account or investment. To determine these two items it is necessary to know the value of the capital account, which includes such items as the value of land, treatment units and all improvements made up to the time when the costs are being prepared. In general three different ways of determining value, giving in many cases considerably different results, have been advocated. These are:

1. Present reproduction cost (new) of sewage works, less depreciation.
2. Present reproduction cost (new) of sewage works.
3. Original cost of sewage works, plus cost of improvements made from time to time.

The Establishment of Fixed Charges for Sewage Works

The first method is extensively used in the public utility field where fixed charges are an important item in determining adequate revenues. Privately owned public utilities, in seeking to establish a fair charge for their services, usually place a value on their properties, which is based on reproduction costs new less depreciation. They are allowed by Public Service Commissions to have their charges provide a fair rate of return on this value and also for a depreciation fund, the expenditure of which will maintain the plant in a 100 per cent operating condition. Where such a depreciation fund is set up, the bond issue for building the properties is never paid back through a sinking fund, but the utility companies are permitted to float refunding bond issues when the original bonds expire.

The above method of accounting for and establishing fixed charges for sewage works would undoubtedly prove quite complicated and cumbersome for the average sewage works operator. It is, therefore, not recommended since it would necessitate determining the quantities of all equipment and materials which form a part of the works, assigning present day unit costs on excavation, concrete, stone, etc., and deciding on the probable period of additional usefulness of the various parts of the plant.

It is believed that the simplest way of calculating the charges for sewage works would be to follow method No. 3 and determine the total original cost of the plant, to which should be added the cost of improvements made from time to time. The interest charge and the depreciation charge should then be based on this cost. While the value of money may change to a considerable extent from its value when the sewage works was first constructed, nevertheless, the present day value is the basis of the payment of current interest on bonds at rates established when the sewage works was originally built, which rates were based upon the value of money at that time. The public does not gain or lose materially by this fluctuation in money values. With these facts in mind it is recommended that the fixed charges should be based on the original cost of the sewage works.

The total original cost of a sewage works is the sum of the following items:

1. Basic cost of physical property, including the cost of land.
2. Errors, omissions and contingencies, etc.
3. Engineering and supervision.
4. Organization expense, if any, although this usually does not enter into the cost of municipal structures as in the case of private development.
5. Administration, legal advice, etc.
6. Interest during construction.

To the original cost of the sewage works should be added the cost of all improvements made from time to time.

Interest Charge.—After the total cost of the sewage works is known, it becomes a simple matter to determine the interest charge. This charge is calculated by applying to the total investment cost the interest paid on the stocks or bonds which were floated to finance the sewage works construction.

Depreciation Charge.—In order to calculate the depreciation charge it is necessary to assume a useful life of the sewage works. Unfortunately, little published information is available on this subject. Considerable study has been given to this matter (see Appendix III for an extended discussion). As a result of this study it is recommended that 20 years be assumed as the average life of a sewage works for the purpose of calculating depreciation charges.

Method of Calculating Depreciation.—Several methods are used to calculate depreciation charges. Of these the percentage-on-original-cost plan and the sinking-fund plan have been most widely adopted. In the percentage-on-cost plan the total depreciation, or the difference between the first cost of an asset and its junk value, is divided by the number of years of usefulness of the asset. The dividend is the annual depreciation

charge. Although this method is exceedingly simple, it is not recommended in this instance. In the sinking-fund plan a sufficient sum of money is set aside annually so that it, together with the accumulated compound interest, will equal the total depreciation of the asset at the end of its useful life. The following formula may be used to calculate the annual depreciation charge by the sinking-fund plan:

$$D = \frac{Ci}{(1 + i)^y - 1}$$

where D = Annual depreciation charge,
C = Cost of sewage works less scrap value,
y = Assumed life of sewage works in years,
i = Interest rate expressed decimally.

As the sinking-fund plan for determining depreciation charges has been widely adopted and as it possessed advantageous features not found in other methods, it is recommended as being the most desirable to follow in determining depreciation charges at sewage works. Appendix IV contains an example of how fixed charges at a sewage works may be calculated, and indicates in particular how the sinking-fund method for finding depreciation is used.

For the purpose of determining depreciation charges where a longer or shorter useful life of the sewage works than 20 years is assumed, Appendix V has been prepared.

In case the bonds issued for the purpose of financing sewage works construction mature in 20 years, the money set aside by the city treasurer to amortize them would represent the annual depreciation charge. If, however, the bonds mature at the end of some other period of time, such as 30 years, the recommended depreciation charge or sinking fund would not be the same as the municipal financial statement, which is based upon the actual accounts of the treasurer. In fact, there is no direct connection between the annual depreciation charges under discussion and the payments to retire bonds, which have been sold to finance sewage works construction. This fact may be illustrated by two examples. First, the municipality may not mature the bonds, but may refinance the issue, in which case interest would be paid by the city long after the useful life of the sewage works. Second, the bond issue may mature at the end of a period of greater than 20 years. In this instance the public would still be paying for the sewage works after the end of its useful life. The adoption of either of these procedures would place a portion of the burden of financing fixed charges on taxpayers not directly benefited by the treatment works.

The fixed charges of sewage treatment at various plants, derived by the

above-mentioned method, can easily be determined and compared. It is frequently impossible, however, to compare the cost of sewage treatment at different plants by following the above procedure, because they may have been constructed at different times, when different unit prices prevailed. The actual cost of construction at any date may be calculated on the basis of unit costs for a different date through the use of cost index figures. More accurate comparisons of the costs of sewage works built at different dates may then be made. It is necessary, however, that the fixed charges at the two plants be calculated in the same manner before comparable figures can be determined.

Operation and Maintenance Charges

Terms Used in Cost Keeping.—Before considering the various operation and maintenance charges used in sewage works accounting, the following more important terms used in cost keeping will be defined:

Tangible fixed assets are capital investments consisting of land, buildings, machinery, tools, equipment, etc. In the case of a sewage works the tangible fixed assets consist of the sewage works site, the numerous treatment units, buildings, roads, conduits, etc.

Additions are all structures, machinery, properties, etc., added from time to time to those in service at the time of the addition, and not replacing any of a like nature previously in service. The cost of all such additions should be added to the cost of the tangible fixed assets and charged to the capital account.

Improvements or betterments are physical changes made to the tangible fixed assets for the purpose of improving the physical value or usefulness of the fixed assets. The cost of that portion of the improvement or betterment which, when added to the original cost of the property bettered, will give the cost of the reconstructed property in its present condition, should be charged to the capital account. The remainder of the cost should be classed as a repair and should be charged to the maintenance account. For example, an old pump impeller costing $100 is replaced by a new one costing $150 in order to increase the capacity of a centrifugal pump, which cost $2000. Of this expenditure $50 should be charged to the capital account and $100 to the maintenance account.

Replacements consist of the substitution of equipment and property, which is generally new, for old equipment of the same capacity. All replacements should be charged to the capital account, and the cost of the old plant and equipment which has been retired should be deducted from the capital account. Small parts of an individual unit frequently have to be replaced many times during the life of the unit. These replacements should not be charged to the capital account but to the maintenance expense account.

Depreciation is the constant decrease in value of tangible fixed assets due to wear and tear, decay, obsolescence, inadequacy, accident, etc., which will require the abandonment or replacement of the fixed assets at some time in the future, in spite of the ordinary current repairs which are made.

Scrap value is the selling price of a fixed asset less the cost of delivering it to the buyer.

Operating expenditures are those expenditures for labor, materials and supplies which are used in the operating process and which do not increase the value of the fixed assets.

Maintenance expenditures are those expenditures for labor, materials and supplies which maintain or preserve the fixed assets in a good operating condition. All incidental repairs which do not materially add to the value of a fixed asset or appreciably lengthen its life should be charged to maintenance expenditures.

Charge Accounts

The keeping of costs should consist of determining the cost of operating and maintaining the various treatments units. These costs can best be obtained by setting up a group of charge accounts, each of which represents some phase of the treatment process. All materials and labor used during a definite time interval to operate and maintain the various treatment units and other appurtenances can then be segregated in a proper manner.

Operation and maintenance cost accounts fall in two groups: (1) expense accounts and (2) revenue accounts. The former covers all expenditures involved in operating and maintaining the works, and the latter includes all money received from the sale of screenings, sludge, gas from sludge digestion, etc.

Schedule V lists the expense and revenue accounts, based on the prevailing types of treatment units to be found at the present time in sewage works. It is believed that this schedule is in sufficient detail to meet most needs. Additional items may be added where necessary or two or more items may be combined for simplicity. It is understood, of course, that only a portion of the enumerated items will apply to a single plant.

SCHEDULE V. OPERATION AND MAINTENANCE COST ITEMS

Expense Account

1. Supervision
   A. Indirect
      A proportionate amount of salaries paid the mayor, city council, legal department, comptroller, chief engineer and all administrative and supervising groups.

B. Direct

- Works superintendent
- Chemists
- Clerks
- Timekeepers
- Storekeepers, etc.
- Experimental work relating to works operation
- Office and laboratory supplies, printing and postage
- Telephone and telegraph
- Insurance
- Taxes
- Traveling and transportation
- Automobiles and trucks

2. Pumping sewage
3. Coarse screens
4. Fine screens
5. Disposal of screenings
6. Grit chambers
7. Grease removal
8. Preliminary settling tanks
9. Dosing devices
10. Trickling filters
11. Contact beds
12. Intermittent sand filters
13. Broad irrigation
14. Final settling tanks
15. Aeration equipment (activated-sludge treatment)
16. Aeration tanks (activated-sludge treatment)
17. Reaeration tanks (activated-sludge treatment)
18. Disinfection. With chlorine, calcium hypochlorite, etc.
19. Odor control
20. Final disposal of effluent
21. Sludge pumping and handling
22. Sludge digestion
23. Gas collection and utilization
24. Sludge thickening and conditioning
25. Sludge drying beds
26. Sludge filtering or pressing
27. Heat drying and preparing sludge for final disposal
28. Sludge lagooning, trenching or burying
29. Sludge disposal at sea
30. Final disposal of dried sludge. To dumps, farmers, etc.
31. Sewer conduits, pipe lines, electric conduits and cables, etc.
32. Buildings, roads and grounds

Revenue Account

1. Budget appropriation
2. Receipts from sale of:
   - A. Screenings
   - B. Grit
   - C. Sludge
   - D. Farm products
   - E. Gas from sludge digestion
   - F. Junk, discarded materials and equipment
3. Rental of property

Expense Account

Supervision.—The supervision account has been divided into indirect and direct accounts. The indirect account includes a proportionate amount of the salaries paid the mayor, city council, legal department, comptroller, consulting engineer, chief engineer and all administrative and supervisory groups. The cost can best be estimated. One way of doing this is to determine what is the percentage of the cost of operating and maintaining the sewage works to the total cost budget of the city. By taking this percentage of the salaries of all persons included in the administrative and supervisory groups, the amount of the indirect supervision account can be determined. It frequently happens that one or more persons acting either in a supervisory or other capacity, but not

necessarily employed at the sewage works or appearing on its pay roll, will devote considerable time to the operation of the works. Either an accurate account of this time should be kept or it should be estimated and charged accordingly.

The direct supervision account should include the salaries of the superintendent, chemists, clerks, etc., together with office and laboratory supplies. Traveling and transportation expenses should include such items as traveling expenses to meetings of sewage and other associations and societies, and also to other sewage works for purposes of inspection. Where the town or city pays the bus or car fare of its employees to the sewage works, the expenditure should be included in the direct supervision account. The cost of operating and maintaining automobiles used for general purposes of transportation should also be included in the above account. Where trucks are used, however, it will usually be feasible to charge the cost of operating the truck to the account of that treatment unit which is being served by the truck.

Pumping Sewage.—Where a sewage works is provided with a pumping station for lifting the sewage, a record should be kept of all costs involved in operating and maintaining the station, including such items as labor, electric power, coal, oil, miscellaneous supplies, etc. Where the pumping costs are a major item, it may be desirable to segregate these costs further into several items such as boiler room costs, pump room costs, etc. A record should be kept of the total head against which the pumps operate, and the cost of pumping sewage per million-foot gallons should be calculated.

Coarse Screens.—The cost of screening the sewage will involve such items as labor used to clean the screens, electric power used to operate mechanically cleaned screens, repairs, etc.

Fine Screens.—See above comment regarding coarse screens.

Disposal of Screenings.—The cost of the disposal of screenings should include all items of expense in handling the screenings from the time they leave the screens until their final disposition. The items of expense will be different, depending upon what is done with the screenings. Such items as the operation of belt conveyors, hauling in trucks, handling by ejectors, dewatering by pressing and incineration, burying, etc., are chargeable to this item.

Where the sewage works is small and the expenditures are not large, it may be desirable, for the sake of simplicity, to include the cost of the disposal of screenings with the cost of operating the screens.

Grit Chambers.—Costs involved in operating and maintaining grit chambers consist of such items as labor and electric power used in removing the grit, together with the cost of hauling the material to its final point of disposal. Where the cost of disposing of the grit after its removal from

the grit chamber involves a considerable expenditure, it may be desirable to set up a separate charge account to cover the cost of grit disposal. This procedure may be especially feasible where grit is washed and prepared for subsequent use.

Grease Removal.—The cost of grease removal includes the cost of the operation of especially designed tanks for this purpose. Where chemicals are used to coagulate the grease, their cost should be included. If special treatment is given the grease in order to purify and prepare it for sale, it would possibly be advisable to charge off all such expenses to a separate grease recovery account.

Preliminary Settling Tanks.—The cost of treating sewage in preliminary settling tanks will include such cost items as labor, electric power where it is used to drive mechanical sludge removing devices, removal of sludge by gravity to sludge digestion tanks or lagoons, skimming and squeegeeing.

Dosing Devices.—The cost of operating dosing devices used to apply sewage to trickling filters, contact beds and intermittent sand filters will include the cost of maintaining these devices. Where a butterfly valve or other similar equipment is used for the purpose, the cost of electric current should be charged to this account.

Trickling Filters.—Trickling filter costs include cleaning and repairs of filter nozzles, washing and replacing filter media, and chemicals used to control the growth of *psychoda* flies and to prevent the clogging of filter media.

Contact Beds.—The cost of treating sewage on contact beds includes the cleaning and the replacing of the media in the beds.

Intermittent Sand Filters.—Costs involved in the treating of sewage on intermittent sand filters include the preparation of the surface of the beds for the intermittent application of the sewage, the cost of periodic sand replacement, and the cleaning of underdrains.

Broad Irrigation.—The cost of treating sewage by broad irrigation should include the cost of preparing the ground for crops, planting and harvesting.

Final Settling Tanks.—See above comments under *Preliminary Settling Tanks*.

Aeration Equipment.—The cost of operating aeration equipment in activated-sludge tanks should include the cost of electric or steam power, labor and repairs. Where compressed air is used the total quantity of air handled by compressors or blowers should be recorded.

Aeration Tanks.—The cost of treating sewage in aeration tanks should include all labor and materials involved in operating and maintaining these tanks.

Reaeration Tanks.—See comments above under *Aeration Tanks*.

Disinfection.—The cost of disinfection should include the cost of all chemicals used for this purpose, the cost of all repairs, together with the cost of all labor involved.

Odor Control.—Where odor control is practised by the application of chlorine or by other means, separate costs of this item of sewage treatment should be kept.

Final Disposal of Effluent.—In some instances the sewage effluent requires further treatment after it discharges into a water course, as for example the treatment of the diluting body of water with copper sulphate or chlorine to control algae growth. Where this or any similar treatment is practised, segregated costs should be kept.

Sludge Pumping and Handling.—Where sludge is pumped from settling tanks to digestion tanks, from digestion tanks to sludge drying beds, or from one part of the works to another, the cost of the pumping should be kept. The quantity and cost of electric power used should be recorded. The cost of all labor and repairs to the equipment should be kept.

Sludge Digestion.—The cost of sludge digestion should include labor and materials involved in operating and maintaining sludge-digestion tanks. If the sludge is heated by means of hot water in coils or by heat exchangers the cost of operating and maintaining this equipment should be recorded. Where sludge is digested in two-story tanks, the cost of settling the sewage and digesting the solids should be combined in one charge account.

Gas Collection and Utilization.—The cost of collecting and utilizing gas will cover the cost of operating and maintaining gas mains, gas meters, flame traps, gas boilers, hot water heaters, gas holders, gas purifiers and other equipment.

Sludge Thickening and Conditioning.—Sludge thickening and conditioning costs should include the cost of all chemicals used for this purpose, together with the cost of operating and maintaining all equipment used in the process.

Sludge Drying Beds.—The cost of dewatering sludge on drying beds should include the removal of the dried sludge from the beds and the cost of maintaining the beds in good repair by the replacement of sand or other filtering materials.

Sludge Filtering or Pressing.—The cost of dewatering sludge by sludge filters, by presses or other similar means should include the labor involved in the process and all power used, together with the cost of labor and materials involved in making repairs.

Heat Drying and Preparing Sludge for Final Disposal.—The cost of heat drying, grinding, storing, bagging, etc., of sludge should include the cost of all fuel, power and labor involved in the process, including other operating, maintenance and repair charges.

Sludge Lagooning, Trenching or Burying.—Sludge lagooning, trenching and burying costs include the building of embankments and dikes, the digging of trenches and pits and all other labor and materials used.

Sludge Disposal at Sea.—The cost of disposal of sludge at sea should include the cost of operating and maintaining all ships, barges, tugs and other equipment involved in such disposal.

Final Disposal of Dried Sludge.—The cost of finally disposing of dried sludge to sludge dumps, to farmers, etc., should include the cost of handling and hauling the sludge.

Sewer Conduits, Pipe Lines and Electric Conduits.—The cost of maintaining all sub-surface structures at the sewage works such as sewer conduits, water, gas and electric conduits, etc., should be kept as a separate charge, and all labor and materials used to maintain and keep these structures in repair should be properly recorded.

Buildings, Roads and Grounds.—The cost of repairing and maintaining buildings, roads and grounds should be kept. Where a building, such as a screen house for example, is used to house some particular treatment unit or process enumerated above, the cost of maintaining the said building should preferably be charged against the specific treatment process in question.

Revenue Account

Budget Appropriation.—The budget appropriation, usually provided annually by the municipal appropriating body, shall be set up as a receipts account, to which the various expense accounts shall be charged. In some localities funds for operating sewage treatment works are obtained through the instrumentality of sewer rental laws. It is understood that the various subdivisions, under which the appropriating body provides funds for plant operation, are in no way connected with the above-mentioned itemized expense accounts.

Sales Receipts.—The receipts should be recorded from the sales of all by-products, materials, etc., such as screenings, grit, sludge, farm products, gas from sludge digestion, junk and discarded materials and equipment.

Rental of Property.—Where a portion of the sewage works or any buildings thereon are rented or leased, a record should be kept of the receipts.

When the costs have been segregated in accordance with Schedule V, the various costs of sewage treatment should be calculated as indicated in the following tabulation:

I. Fixed Charges (Interest and Depreciation)
   1. Cost yearly
   2. Cost per million gallons of sewage treated
   3. Cost per capita served

II. Operating and Maintenance Charges
   1. Cost yearly
   2. Cost per million gallons of sewage treated
   3. Cost per capita served
   4. Cost of each cost item (See Schedule V)

III. Fixed Charges plus Operating and Maintenance Charges
   1. Cost yearly
   2. Cost per million gallons of sewage treated
   3. Cost per capita served

All cost reports should be accompanied by a statement giving the salaries paid common and skilled labor. These data are of particular value in comparing the cost of sewage treatment at the same plant at different times or the cost at different plants at the same time. The reporting of work accomplished in man-hours, where possible, is also of great value.

Time Interval.—Sewage treatment costs should be summarized at the end of definite time intervals, which in this report is recommended to be at least once every calendar year. Where it is felt to be expedient or necessary, more frequent cost summarizations should be made, preferably once a month.

Cost Forms.—It is not the purpose of this report to recommend the type of cost forms to keep. The kinds of sewage treatment are so varied that a form applicable for one installation would not be suitable for another. Furthermore, it may be found desirable to keep more detailed records at a large sewage works than at a small one. The records, however, should be kept so that the costs can be quickly and readily summarized, and the cost of sewage treatment determined for any time interval.

APPENDIX I

Recommended Analyses to Be Made at English Sewage Works

In the publication of the Ministry of Health of England (1929), entitled "Methods of Chemical Analysis as Applied to Sewage and Sewage Effluents," the following tests are recommended:

For All Sewage Samples
- Suspended Matter
- Free and Saline Ammonia
- Albuminoid Ammonia
- Oxygen Consumed by Permanganate (special methods)
- Chlorides

For Sewage Effluents in Addition to above
- Nitrites
- Nitrates
- B. O. D. (Royal Comm. Test)

For Small Sewage Works
- Oxygen Consumed by Permanganate, 3 min. and 4 hr.
- Incubator Test (for putrescible odors)
- Indigo Reduction Test (special putrescibility)

For Sludge
- Moisture
- Alkalinity or Acidity
- Grease
- Organic Nitrogen
- Mineral and Organic Matter

APPENDIX II

Analyses Made at Sewage Works in the Essen District, Germany

In the publication "Twenty-Five Years of the Emscher District (1900–1925)" a tabulation of the performance of various sewage works (pp. 298) shows that the following analyses were made:

Suspended Solids
- Total
- Mineral
- Organic

Dissolved Solids
- Total
- Mineral
- Organic

Chlorides

Nitrogen
- Total
- Ammonia
- Organic
- Nitrate
- Nitrite

Dissolved Hydrogen Sulphide

Settleable Solids cc. per liter (2 hr. settling)

Results of later years, 1919–1923 (pp. 302 and 304) give additional analyses as follows:

Sulphur
- Total
- Sulphate
- Residual Sulphur from Sulphides and Organic Compounds

Oxygen Consumed by Permanganate

Temperature
- Air
- Sewage

Putrescibility—days

B. O. D.—5 days

On wet digested sludge the following analyses are reported:

Dry Solids at 100° C.
- Mineral
- Organic

Fats

Total Nitrogen (Kjeldahl)

Fixed Carbon

Volatile Carbon

APPENDIX III

The Useful Life of Sewage Works

The literature on sewage treatment contains little information regarding the life of sewage works. During the past 30 or 40 years, however, many sewage plants have been built and later abandoned or replaced by new works. It was felt that information regarding these installations would be of material help in determining the average life of sewage works. A questionnaire asking for information regarding the life and the reasons for abandoning sewage works was sent to 25 State Boards of Health where active sewage treatment programs exist.

Information regarding a total of 141 sewage works, which had been abandoned or replaced, was obtained. Of this group two plants had a minimum useful life of only one year, whereas the maximum life was 29 years. The average period of usefulness was approximately 15 years, and the median period about 12 years. Unfortunately, it was impossible to secure information relative to the probable period of usefulness of other sewage works, which are still being operated, so that the data on the 141 plants represent a somewhat shorter period of usefulness than would be the case were those plants which are still in operation, likewise included.

The data indicate that 175 reasons were given for the abandoment of these 141 sewage works. Some plants were, therefore, abandoned for more than one reason. The data have been tabulated as follows:

Reasons for Abandoning Sewage Works	*No. of Times Indicated*
1. Poor design	3
2. Poor location	4
3. Insufficient treatment	6
4. End of useful life	14
5. Poor operation and maintenance	14
6. Obsolete	23
7. Objectionable odors and undue pollution of streams	49
8. Too small	62

It is significant to note that the chief reason for abandoning sewage works is insufficient capacity and the production of odors. This condition naturally results from the growth of communities and municipalities, which growth increases the volume of sewage to be treated and also leads to the construction of dwellings in the vicinity of the sewage works. Most of the plants reported as abandoned because of objectionable odors, however, are in Texas and California. Therefore, climatic conditions seem to be of great importance.

One might think that sewage plants of various types have materially different periods of service. An examination of the data in the following table, however, indicates that this is not the case.

Sewage Treatment Equipment	*Length of Service in Years*	
	Average	Median
Screens	14	
Septic Tanks	16	17
Imhoff Tanks	10	11
Trickling Filters	12	10
Contact Beds	14	15
Intermittent Sand Filters	15	
Activated Sludge	11	

It is believed that this tabulation does not rightly indicate the average period of usefulness of similar units when they are designed with due consideration to future growth, satisfactory operation, etc., but they do indicate that the periods of usefulness of many treatment plants are much shorter than is frequently considered to be the case. There are indications at present that sewage works are now being designed in a more rational manner and that improved operation is resulting. Nevertheless, great advances in the treatment of sewage will most likely occur in the future and it cannot be assumed that sewage works being built today will have a materially greater period of usefulness than the older plants. It is, therefore, recommended that 20 years be assumed as a satisfactory period of usefulness for computing depreciation. It is realized that some minor units at sewage works will last for a much shorter period, but the cost of their replacement should be charged to maintenance. When a fixed asset of major importance becomes obsolete or useless, however, its replacement should be charged to the capital account, and the original value of the replaced unit should be deducted from the capital account.

APPENDIX IV

Example Illustrating Method to Be Followed in Calculating Fixed Charges at Sewage Works

The following is an example used to illustrate how the fixed charges at sewage works may be calculated:

Item	*Amount*
I. Base Cost of Physical Property with Land	
1. Sewage works	$ 87,000
2. Sewage works site: 20 acres at $100	2,000
	$ 89,000
II. Miscellaneous Construction Expenditures	
1. Errors, omissions and contingencies	
Base cost	$ 89,000
$89,000 × 2% (1) = $1780	
2. Engineering and supervision	
Base cost	$ 89,000
Errors, omissions, etc.	1,780
	$ 90,780
$90,780 × 6% (1) = $5447	
3. Administration, legal advice, etc.	
Base cost	$ 89,000
Errors, omissions, etc.	1,780
Engineering and supervision	5,447
	$ 96,227
$96,227 × 2% (1) = $1924	
4. Interest during construction	
Base cost	$ 89,000
Errors, omissions, etc.	1,780
Engineering and supervision	5,447
Administration and legal advice	1,924
	$ 98,151
$98,151 × 2¼% (2) = $2208	
III. Total Overheads Added to Base Cost with Land	
Base cost	$ 89,000
Errors, omissions, etc.	1,780

	Engineering and supervision	5,447
	Administration and legal advice	1,924
	Interest during construction	2,208
		$100,359
IV.	Interest Charge	
	Total first cost of works	$100,359
	Annual interest on bonds	4½% (3)
	Interest charge $100,359 at 4½%	4,516
V.	Depreciation Charge	
	Total first cost of works	$100,359
	Value of sewage works site $2000	
	Junk value of sewage works $1000	
	Total scrap value	3,000
	Total Depreciation	$ 97,359
	Assumed life of sewage works	20 years
	Interest rate on annual annuity	3½% (4)

$$\text{Annual depreciation charge } D = \frac{Ci}{(1+i)^y - 1}$$

$$= \frac{\$97{,}359 \times 0.035}{(1+0.035)^{20} - 1}$$

$$= \$3442$$

(1) These percentages have been assumed for convenience in calculation. They are believed to be approximately correct, and where actual cost data covering these items are not available they may be used in determining the total first cost of the sewage works.

(2) The interest rate during construction of 2¼% is based on the assumption that it would take one year to build the sewage works and that the interest rate on the bonds would be 4½%.

(3) An annual interest charge of 4½% on bonds has been assumed for illustrative purposes. The actual interest charge on bonds used to finance the construction of the sewage works in question should be used.

(4) The interest rate on the annual annuity will vary slightly from time to time. It is recommended, however, that an interest rate of 3½% be used.

APPENDIX V

Annual Annuity Required to Accumulate $1.00

Number of Years	Rates of Compound Interest 2½%	3%	3½%	4%	4½%
10	0.08926	0.08723	0.08524	0.08329	0.08138
15	0.05577	0.05380	0.05183	0.04994	0.04811
20	0.03915	0.03722	0.03536	0.03356	0.03187
25	0.02928	0.02743	0.02567	0.02401	0.02244
30	0.02278	0.02102	0.01937	0.01783	0.01639
35	0.01821	0.01654	0.01499	0.01358	0.01227
40	0.01484	0.01326	0.01183	0.01052	0.00934

This table gives the installments necessary to be set aside annually in order to accumulate any sum of money for various periods of time at various interest rates Thus the annual installment necessary to accumulate $175,000 in 30 years at 4% compound interest is $175,000 × $0.01783, or $2920.25.

Sewage Research

"Bound Water"—Changes during Sludge Digestion

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As the result of considerable study it has been found possible to reduce materially the time required for bacterial decomposition of sludge.[1] It appears, however, that the practical benefit of this operation depends upon the speed with which the remaining sludge may be dried. It has been determined that most of the organic settleable solids in sewage may be completely digested in ten to fourteen days. Ostensibly then, this mixture, a black emulsion of not unpleasant petrol-like odor and jelly-like consistency, is ready to be transferred to sand beds where it is expected to drain and dry to a friable earthy mass. However, it has been observed that if this fourteen-day sludge is run onto the beds for drying it does not dry quickly and that it may require a much longer period for drying than if the sludge had been digested seventy-five days and then run onto the beds.

It has been observed in the studies of two-stage sludge digestion that although gasification is practically complete in the short period of ten to fourteen days and although the chemical properties of the fourteen-day sludge are in every way identical with those properties of sludge digested for longer periods, yet there is a marked physical difference in the character of the two sludges. Studies indicate that the only type of activity confined to the second period of digestion, or that following the period of rapid gasification, is one of dehydration or dewatering.[2]

To take full advantage of the accelerated digestive action it will be necessary to devise a method for drying the digested sludge in winter. If this cannot be done, it will still be necessary to provide tanks of sufficient size to store the sludge over winter. These tanks will of necessity be large enough to provide the customary long digestion period, consequently the ability to shorten the digestion period becomes of limited practical benefit.

Sewage sludge contains an appreciable portion of colloidal material, which is no more than matter in a meta-stable state, and one of its chief characteristics is its tendency to adsorb water.[6] To say the same thing in another way, the colloid particles tend to fix or bind water. These solvent molecules then operate in the rôle of "bound water." Since we are dealing

essentially with a colloidal system we would expect the same laws and observations to hold in this case as in those dealing with more uniform materials. Although the theories advanced for explanation of the behavior of colloidal jellies have not advanced beyond qualitative speculation, the results of certain operations are well confirmed.[5] Among these is the fact that jellies which we consider to be a type of colloidal solution do maintain a kind of equilibrium between the disperse phase and dispersion medium.[3] If we are dealing with gelatin and water, a portion of the latter, the dispersion medium, actually enters into combination with the gelatin and equilibrium is set up.[4] A certain percentage of water is "bound." Now it can be shown by experiment that this colloid-water equilibrium may be disturbed in several ways, namely, by the addition of electrolytes, variation of the temperature, change of pH and often quite simply by aging.[6,7] The results of these operations indicate that the reaction is quite often shifted irreversibly to the most stable state characteristic of the particular environment imposed upon it. Since we are dealing with a system in these sludges that is colloidal in nature we would be led to predict from behavior in well-defined systems that aging would tend to produce a loss of water-binding properties.[7,9]

It is highly important, then, to shorten the "life-period" of these colloids thus speeding up the loss of the water-binding tendency. To do this we must know the factors which affect the increase or decrease of water-binding properties and to know these a measuring-stick must be found by which the percentage or relative amounts of bound water in sewage sludges may be determined, so as to show the quantitative effect of each variable.

This research then has as its object the development of a practical technique that will permit either the determination of the percentage of water associated with sludge colloids; or a method that, at least, will serve to indicate the relative amounts of bound water held by a sample of sludge at different periods of age—thus serving as a developable criterion of sludge ripeness, inasmuch as the relative amounts of bound water change in the processing or aging of sludge.[8]

A brief résumé of the limitations of the principal methods that have been developed for the determination of colloidally imbibed, adsorbed or associated water will offer the best argument as to why it was necessary to carry out further experiments for a new technique.

Early workers in the field of colloid chemistry observed that colloid particles appeared to act, under certain conditions, as though they possessed an electrical charge. The magnitude of this charge is claimed by some to be a function of the thickness of the layer of ions fixed to the surface of the colloidal particle.[10] In the case of water as the solvent this layer might well be composed of hydrogen and hydroxyl ions adsorbed upon the surface of the solid particle in different rates or amounts.[17] That is to say, the

intensity of the surface charge would be proportional to the amount of bound water. Although means have been devised to measure the intensity of this function, which is called the "electro-kinetic potential"[10] in the case of sludge it would be necessary to measure the extent of the adsorbed film about these particles. It has been pointed out that "The hydration of ions stands essentially on qualitative experiments and up until now (1928) we have only a general idea of the order of hydration of the ions, no really quantitative data on the amount of hydration are available. The question of the hydration of colloids stands on a worse footing and even preliminary qualitative experiments have hardly been made, yet we can get certain indirect evidence with regard to the state of hydration of colloids."[11]

These indirect lines of evidence available for the determination of the degree of hydration include the necessity for measuring some such physical property as transport numbers,[12] surface tension, extent of swelling, vapor pressure,[13, 29] optical properties[14] or viscosity.[18] Since sewage sludges are opaque, jellylike, of variable constitution, slowly evolving gas and of a type whose constitution is irreversibly altered when once they are dried, we see at once that any attempt to apply such determinations to a material of this kind would be highly impractical. However, as previously cited, these qualitative hydration experiments apparently indicate the existence of layers of water, differentially held, which are distinct from the main portion of the dispersion medium. Although the methods cited are not applicable for sludge, since it is colloidal, it is safe to assert that a similar situation exists in sewage sludge as in the types studied, and layers of water are held the same as in other colloidal solutions.

Later experiments made use of the physical observation that increase of the surface of a material in proportion to its mass increases the surface energy and thus lowers the melting point.[15,30,31] Thus a sample of a finely powdered organic compound will have a slightly lower melting point than a sample composed of very coarse crystals. The dissolution of water polyhydrols into monohydrol layers in biological substances increases surface energy and decreases free water. These effects are presumed by some authors to be an explanation of the abnormal depression of the freezing point.[16] Of course, this is open to the question as to whether it is due to a change in surface energy by dispersion or because of the removal of water from solution by "fixing."

Evidently application of some such idea is noted in the technique of Gortner[19] and of Theones.[19] The first of these investigators observed a high degree of correlation between the hardness of winter wheat and the percentage of sap that he was able to express from the leaves of these plants. He observed that the more hardy plants retained a very much higher percentage of moisture under pressure than did those of a less hardy variety.

He accepted this as an indication of the existence of a very much higher percentage of bound water in the hardy strains of wheat and set about to develop a method that would quantitatively indicate the amount of bound water.

Gortner assumed that water molecularly dispersed on cell walls or fixed by colloids could not be used to effect solution of a compound. Essentially he carried out the following experiment. He expressed a quantity of sap from the leaves of wheat and determined the freezing point of the sample. Noting the weight of the original solution, he arranged it so that it should contain exactly ten grams of water. To this was added a fraction of a mole of sugar. The freezing point depression was again taken and the excess over the theoretically calculated value used to calculate the amount of bound water, since the colloidal water, if not free to effect solution, would thus produce an apparently higher concentration than the total water content indicated.

Theones modified this idea as follows. He assumed the bound water did not freeze and free water did so at $-20°$ C., so he cooled the samples to $-20°$ C., and immersed the sample at a higher temperature, $+T°$, in a thermostat and measured the amount of heat required to melt the ice formed at the lower temperatures and to bring the lot to equilibrium. The total percentage of water in the gel was also determined. The percentage of free water was determined by this process of freezing and melting. The difference between the total water and the free water content was taken as an index of the percentage of bound water.

This technique rests wholly upon the assumption that the bound water is independent of these temperature variations. As it is known that some colloids release water with decrease in temperature and others increase the amount fixed; and inasmuch as the findings of Richardson and Scherubel[20] point to some fundamental change in the gel structure by freezing it was not deemed advisable to attempt the adoption of a technique that gave every evidence of disturbing the state of the system in the course of its operation. Moreover, it was hoped to initiate a method as applied to sludge that would not disturb the system before application and at the same time would be rapid and relatively inexpensive to apply in a small laboratory.

Another method used in studies of this type by previous authors employs the property of heat of hydration or wetting of a substance.[21,32,33,34] In this procedure both the heat of wetting of a gel was determined as well as the thickness of the film formed in wetting. Thereupon, the rate of change of the heat of wetting with respect to the thickness of the film was plotted as an ordinate against the thickness of the film. The thickness of the film corresponding to the value where this differential was equal to zero was then used to calculate the percentage of water bound by the colloid. This procedure, however, requires not only a reversible hydration-dehydration equilibrium but is also open to all the difficulties surrounding the deter-

mination of the thickness of films. The conditions imposed by this procedure could not be fulfilled by sludge.

The hysteresis shown in the hydration-dehydration curves of the silicic acids affords an excellent argument for the existence of water differentially held, in which a reversible equilibrium does not exist.[22] Once dehydrated, the hydrophilic character of the materials has been altered in an irreversible manner. The extent of the divergence in the hydration-dehydration curves might be taken as a direct index of the bound water. However, this technique, which depends on vapor pressure measurements, likewise proved to be unsatisfactory inasmuch as digested sludge slowly evolves gas, which would invalidate such measurements.

In this failure of many compounds to maintain an unrestricted hydration $\rightleftarrows$ dehydration equilibrium, which is so intimately associated with the idea of bound water, we find that the problem of colloidal moisture has ramifications in every line of human interest. The medical profession has already accepted it as the basis for a theory of fever, assuming a free water $\rightleftarrows$ bound water equilibrium in normal organs.[23] Any disturbance of this equilibrium is assumed to produce pathological conditions. Many industrial plants that must have dust-free air find washing is in part ineffective.[24] Likewise, the percentage of material that is not wetted has assumed important proportions in chemical warfare and furthermore this problem is important in the flotation industries. This digression was inserted simply to point out that bound-water problems are as important to the astronomer in his explanation of the blue in the sky as they are to the sewage chemist who is interested in dewatering sludge.

A technique used by mineralogists to determine characteristic groups in minerals depends upon the absorption of infra-red light by compounds.[25] Water held in different manner has been observed to exhibit very different absorption spectra. Free water and water of dehydration do not display the same spectrum as that of colloid water in gelatin. Here the water seems to display the properties of water that is constitutionally united, as in the carbohydrates. Determination of absorption spectra might give a method for determining the state and presence of colloid water in different types of substances, but no publications have as yet indicated a successful adoption of what is undoubtedly the most rigorous method of analysis of such a solution, since no disturbance in the sol results in the course of its study. Added difficulties would result in the use of this method for opaque gels, and it appears to be of little promise as applied to sewage sludge.

It did not seem probable that a method dependent on electrical conductivity, dilatation or dielectric constant would be so feasible or practical as the one selected for examination. Electrical conductance methods have never contributed more than a relative idea of hydration, so that further investigation might not hope to extend this. A recent publication by

Seborg and Stamm[26] indicates the truth of this assertion. Of course the per cent to which watery sludge systems are ionized disqualifies application of the dielectric constant.

The dilatometer was used by Reinke[35] and MacDougal[36] to measure the amount of swelling by a colloid. By means of a needle indicator fastened to a horizontal upright, the swelling was measured by the angular

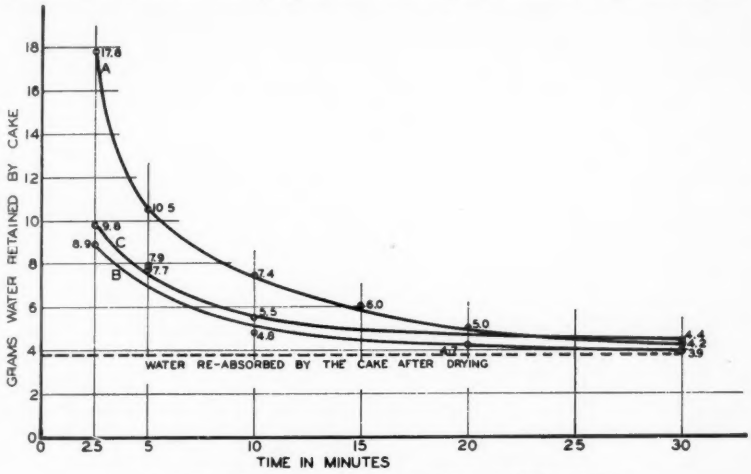

FIG. 1.—The Effect of Pressure on Sludges of Different Ages.

Fourteen day digestion. Seventy-five day digestion

10–14 Day Sludge: A. Sept. 17 Sludge: 3000 lbs. pressure 2(17.8–4.2) 27.2% H_2O change, 3.5 gm. solid.

70 Day Sludge: B. Sept. 17 Sludge: 3000 lbs. pressure 2(8.9–3.9) 10.0% H_2O change, 3.5 gm. solid.

70 Day Sludge: C. Decatur well-digested sludge: 3000 lbs. pressure 2(9.8–4.4) 10.8% H_2O change, 5.5 gm. solid.

distance through which the pointer moved, its movement being controlled by direct mechanical attachments to a piston which traveled under the expansion of the colloid. Illustrations of this piece of apparatus may be found in most texts. However, an interesting article by Gustavson[27] gives the following conclusions about this method of measuring protein hydration. "The total volume changes in the system of gelatin-aqueous solutions of various H-ion concentration are not a measure of the degree of hydration of the gelatin."

Since it appeared that bound water might be responsible for the failure of sludge to dry in a short time, it seemed reasonable to assume that this water, fixed to the colloids, which could be completely removed upon drying at 105° C. and all of which could not be reimbibed by the dehydrated

material, must have a varying degree of fixation which would continue to decrease with age. Heat apparently reduces the degree of fixation of water by work against the pressure of imbibition. It was decided to try to subject the sludge to pressures for varying intervals of time, with the prediction that a larger per cent of water would be held under these pressure-time treatments by the ten to fourteen day digested sludge than by the seventy-five day digested sludge. That is, a well-aged sludge will retain little water when pressed—a raw sludge will hold water tenaciously under like conditions. Our predictions appear to be confirmed as illustrated in Figure 1, which represents the results of preliminary experiments.

TABLE I

DATA ON SLUDGES: A, B, C UNDER 3000 POUNDS PRESSURE

	Grams Water Retained by the Cake	Time Pressure Was Maintained, Minutes
Sludge A: Source Experimental Plant University of Illinois	17.8	2½
	10.5	5
	7.4	10
Digested 15 days	6.0	15
Moisture 93 per cent	5.0	20
Ash 43 per cent	4.2	30
Sludge B: Same sample as "A" after 60 days additional digestion	8.9	2½
	7.7	5
	4.8	10
	4.2	20
	3.9	30
Sludge C: Source: Decatur Sanitary District	9.8	2½
	7.9	5
Digested 75 days	5.5	10
Moisture 89 per cent	4.4	20
Ash 62 per cent	4.4	30

Curve A represents the water retained by fifty-gram samples of a sludge which had been digested for approximately ten to fifteen days. The pressure maintained on the cake by means of a Carver Laboratory Press was 3000 pounds; temperature 27° C. The time of expressing the water has been varied from 2.5 to 30 minutes. Pressures ranging from 100 pounds to 20,000 pounds have been employed in other experiments. The same type of semi-parabolic curve has been noted for all pressures from 100 pounds to 20,000 pounds.

Curve B gives the results of a like treatment on the same sludge after standing 60 days. The age of this sludge was then 70 to 75 days.

Curve C gives the results on a sludge that had received a 75-day period of digestion.

The data on which the curves in Figure 1 are based are given in Table I.

The release of water by the 15 day sludge was 27 per cent between 2.5 and 30 minutes and the amount of water retained at the end of 30 minutes

was approximately 4 grams; the cake still held 34 per cent water at the end of 2.5 minutes. This same sludge after standing for 60 days gave results comparable to Curve C in which the water released by pressure between 2.5 to 30 minutes was but 20 per cent while all sludges retained about 4 grams of water at the end of 30 minutes. This is very nearly the per cent moisture that would be predicted as present in the voids of the cake when formed in the press. It has been further observed that when the cakes so found have readsorbed water they readsorb only the amount held by the cake after 30 minutes pressure.

The sludge used to supply data for Curves A and B was that from a typically domestic community. That used for the data of Curve C was supplied from a community where an abnormally high percentage of industrial waste obtains. At this period of experimentation there has been no opportunity to examine different kinds of sludges from several different communities. However, the fact that Curves B and C have been found to be typical of those from well-digested sludges, whereas A is typical of those from poorly digested sludges, indicates quite clearly the extent to which these two types differ in their water-retaining qualities under the same pressures. The absolute height of the ordinate in these curves has been found to vary, depending upon the total moisture of the sludge, yet in every case examined where a poorly digested sludge and a well-digested sludge from the same source were compared in this way the well-digested sludge produced a "flat" curve, while that from the poorly digested sludge had a high degree of curvature. This paper reports preliminary data intended only to correlate the age of a sludge and its water-binding properties, as indexed by pressure effects. The correlation between these results and other variables as pH, ash, total solids, etc., will be indicated at the completion of this work.

As to whether we may be able to show that the amount of water between the readsorption value and Curves A and B gives a measure of the bound water is yet a question. At least it is quite evident, at this stage of these experiments, that a practical test may be opened for the examination of the effect of reagents upon the per cent of water bound in the system and also that this test may be a good index of the ripeness of a sludge, if it is found after further experiments on many samples that Curves B and C represent an average value of many sludges and the minimum water content approached by ripe sludges under this treatment.

Further observations will be announced in more detail at the conclusion of these experimental tests.

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The Effect of Hydrogen-Ion Concentration on the Distillation of Free Ammonia Nitrogen from Sewages and Trade Wastes

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A knowledge of the proportionate amounts of mineralized and organic nitrogen present in wastes is essential for calculations of pollution indices. A proper separation of the free ammonia nitrogen from that found in the organic matter is the keynote of an accurate evaluation of the two forms of nitrogen. Incomplete removal of ammonia nitrogen increases the organic nitrogenous matter expressed as protein, by an error equal in magnitude to 6.25 times the mineral nitrogen not recovered. Likewise the magnitude of the error is just as great but in the opposite direction, *i. e.*, a decrease in protein, if organic nitrogen is hydrolyzed to appear in the free ammonia nitrogen result. The difficulties of separation have contributed to a somewhat general disregard of these results, taken separately, as a means of interpretation of the strength of sewage or other wastes.

The methods in general use have recommended that distillation of free ammonia nitrogen be made from an alkaline solution. Magnesium oxide, magnesium carbonate, calcium carbonate, sodium carbonate and various other alkalinizing agents have been used, without regard to the resultant pH of the distillation mixture. Other methods have advised that the solution to be distilled should be "alkaline to methyl orange" (pH at or above 4.2) or "faintly alkaline to lacmoid" (pH 5.5 to 6.0). That a more careful consideration of the hydrogen-ion concentration is necessary has been indicated in a recent paper.[1] It was shown that at low pH values there is only a partial recovery of free ammonia nitrogen. Thus, when the pH was kept between 5.9 and 5.5, only 33 per cent of the nitrogen available from a solution of ammonium sulphate appeared in the distillate. It was also shown that at high pH values a partial hydrolysis of organic nitrogenous compounds occurs. Between these two extremes there was found a point at which there is complete recovery of free ammonia nitrogen, with little hydrolysis of organic nitrogen compounds. From this study a constant pH of 7.4 was found to be most satisfactory for this separation. In order to maintain this constant pH during distillation, a $M/2$ phosphate buffer solution of pH 7.4 was used. Sodium carbonate was found not to be a satisfactory buffering substance for this purpose. Either the pH does not remain sufficiently high in the distillation mixture for complete recovery when small amounts of sodium carbonate are used, or else it rises to a maximum value greater than 10.6 when larger amounts are present. In the latter case the excessive alkaline intensity tends to produce hydrolysis of organic nitrogen compounds.

The present work is intended to show the application of the method developed in the first study to actual laboratory practice. The three conditions of our experiments were: (1) distillation of the waste without adjustment of the pH value, (2) distillation of the waste by maintaining the pH at 7.4 with 25 cc. of $M/2$ phosphate buffer solution* and, (3) distillation of the waste after the addition of 5 cc. of a 10 per cent sodium carbonate solution. The total volume of the distillation mixture was 250 cc. Initial and final pH values were determined colorimetrically.

TABLE I

SEWAGE AND EFFLUENTS. VARIATION IN FREE AMMONIA NITROGEN

No.	Kind of Waste	No Adjustment Method, pH Variable			Phosphate Buffer Method, pH = 7.4	Na_2CO_3 Method, pH Greater than 10.6
		Initial pH	Final pH	N, P. p. m.	N, P. p. m.	N, P. p. m.
1	Comp. raw sewage	4.6	5.2	1.6	27.2	32.0
2	Comp. plant eff.	4.9	5.6	4.8	48.0	56.0
3	Comp. raw sewage	5.4	8.8	34.0	32.0	38.0
4	Comp. raw sewage	5.8	8.6	40.0	48.0	56.0
5	Comp. final eff.	5.8	8.6	5.6	5.6	5.6
6	Comp. filter eff.	5.3	9.2	36.0	24.0	36.0
7	Comp. tank eff.	6.0	8.6	56.0	54.0	64.0
8	Comp. raw sewage	6.0	8.8	70.0	120.0	140.0
9	Comp. tank eff.	5.4	9.4	34.0	34.0	40.0
10	Comp. raw sewage	6.0	8.9	104.0	140.0	140.0
11	Comp. tank eff.	5.8	9.2	28.0	28.0	28.0
12	Raw sewage	6.1	9.2	48.0	48.0	64.0
13	Comp. raw sewage	6.2	9.2	40.0	56.0	60.0
14	Comp. filter eff.	5.8	9.6	8.0	8.0	8.0
15	Comp. filter eff.	6.4	9.1	46.0	46.0	50.0
16	Comp. tank eff.	6.4	9.1	72.0	68.0	80.0
17	Septic tank eff.	6.0	9.5	120.0	128.0	128.0
18	Comp. tank eff.	6.2	9.4	90.0	100.0	100.0
19	Comp. raw sewage	6.4	9.2	38.0	38.0	38.0
20	Comp. tank eff.	5.8	10.0	42.0	40.0	50.0
21	Raw sewage	6.4	9.4	112.0	108.0	128.0
22	Comp. raw sewage	6.4	9.4	80.0	80.0	80.0
23	Comp. tank eff.	6.4	9.6	38.0	34.0	40.0
24	Comp. filter eff.	6.4	9.6	28.0	24.0	30.0
25	Comp. final eff.	6.4	9.6	50.0	36.0	40.0
26	Comp. plant eff.	6.5	9.6	60.0	38.0	38.0
27	Comp. raw sewage	5.6	10.6	40.0	28.0	40.0
28	Comp. plant eff.	6.6	9.6	24.0	24.0	32.0
29	Raw sewage	6.4	9.8	120.0	120.0	140.0
30	Comp. raw sewage	6.0	10.6	38.4	40.0	46.4
31	Comp. raw sewage	7.1	10.0	20.0	20.0	27.2

* $M/2$ Phosphate Buffer Solution, pH 7.4. Dissolve 14.3 grams of monobasic potassium phosphate (KH_2PO_4) and 90.15 grams of dibasic potassium phosphate ($K_2HPO_4 \cdot 3H_2O$) in enough distilled water to make one liter of solution. (The fractional parts of grams in above amounts may be omitted for practical purposes.)

Distillations were conducted at a uniform rate, using electric heating units, until 200 cc. of the distillate were collected. Appropriate aliquot portions were nesslerized. Such analyses were carried out on 31 sewages, 63 paper mill wastes, 11 beet wastes and 39 milk and creamery wastes, a total of 144.

In Table I are found the results of the analyses on the sewage samples. In all cases pH values greater than 10.6 were not determined.

Inspection of the table shows that sewage and effluents exhibit considerable variation in their initial and an even wider variation in their final pH values. It will be noted that except for the first two wastes the final pH is considerably above the quantitative point of 7.4. In 22 of these cases the free ammonia nitrogen without adjustment of the pH

TABLE II

BEET WASTES. VARIATION IN FREE AMMONIA NITROGEN

		No Adjustment Method, pH Variable			Phosphate Buffer Method, pH = 7.4	Na_2CO_3 Method, pH Greater than 10.6
No.	Kind of Waste	Initial pH	Final pH	N, P. p. m.	N, P. p. m.	N, P. p. m.
1	Filter inf.	4.4	4.6	0.4	6.4	8.0
2	4′ filter	4.8	5.5	0.8	1.2	2.8
3	Filter inf.	4.6	7.7	16.8	19.2	24.0
4	2′ filter	4.7	7.5	14.4	16.8	24.0
5	6′ filter	4.8	7.9	16.0	16.0	24.0
6	2′ filter	5.0	7.7	12.8	13.6	16.0
7	Filter eff.	5.0	7.8	11.2	14.4	20.8
8	Filter inf.	4.8	8.1	13.6	14.4	16.0
9	Filter eff.	5.4	8.4	7.2	9.6	12.8
10	6′ filter	6.8	8.2	11.2	8.8	13.6
11	Filter eff.	7.0	8.0	6.4	8.0	12.0

was equal to or greater than the result using the phosphate buffer. Wastes Nos. 1 and 2 show final pH values considerably below 7.4 and very incomplete recovery of free ammonia nitrogen. Comparison of the last two columns brings out the fact that in 9 cases the results with the sodium carbonate method are equal to those of the phosphate method and in 22 cases greater than the latter. One of these three methods should approximate the correct nitrogen values. In view of the fact that with no adjustment of the distillation mixture the pH varies greatly and that with sodium carbonate there is an abnormally high pH, it is felt that the results in the column headed "Phosphate Buffer Method" give the best evaluation of the free ammonia nitrogen present.

Industrial wastes in general exhibit greater variations in pH values than does domestic sewage, ranging from the very acid sulphite wastes to the strongly alkaline tannery wastes. The results of analyses of the beet wastes studied are found in Table II.

It is to be noted that these wastes have an initial pH value below 7.4 and that the final pH value does not rise much above this value. This result can be interpreted in terms of the free ammonia nitrogen found when no adjustment of the pH is made. Most of the nitrogen results with no adjustment, are lower than those obtained by the phosphate buffer method. On the other hand values shown with the sodium carbonate method support the theory that at this high pH value hydrolysis of nitrogenous compounds occurs.

It is interesting to see that the same general disagreement between the three methods is found with paper mill wastes, as shown by the results in Table III.

TABLE III

PAPER MILL WASTES. VARIATION IN FREE AMMONIA NITROGEN

No.	Kind of Waste	pH Variable Initial pH	pH Variable Final pH	N, P. p. m.	Phosphate Buffer Method pH = 7.4 N, P. p. m.	Na_2CO_3 Method pH Greater than 10.6 N, P. p. m.
1	Digester relief	3.8	3.8	50.0	50.0	140.0
2	Blow-pit sewer	3.8	4.4	4.8	4.8	13.6
3	Digester wash	3.8	4.4	8.0	9.6	16.0
4	Blow-pit waste	4.0	4.2	17.6	22.4	80.0
5	Waste sulphite liq.	3.8	4.5	100.0	100.0	700.0
6	Blow-pit sewer	4.2	4.3	28.0	14.0	56.0
7	Pulp mill sewer	4.4	4.0	4.8	2.6	5.6
8	Main sewer	4.3	4.8	2.6	3.0	6.0
9	Main sewer	4.4	4.6	1.8	2.0	2.4
10	White water	4.6	4.6	0.06	0.08	0.10
11	Blow-pit sewer	4.6	5.2	20.0	27.2	40.0
12	Drain pit sewer	5.2	6.0	0.64	1.12	3.2
13	Paper mill sewer	5.6	5.8	0.16	0.48	0.68
14	W. W. overflow	5.7	7.4	0.56	0.56	0.88
15	Groundwood W. W.	6.2	7.1	0.11	0.22	0.54
16	Wood room sewer	6.2	8.4	6.1	7.0	7.0
17	W. W.-pulp washer	6.0	8.8	0.88	0.48	1.12
18	W. W. overflow	6.4	8.4	0.56	0.40	0.56
19	Paper mach. sewer	6.6	8.2	0.29	0.29	0.70
20	W. W.-bleach plant	6.8	8.1	2.72	2.24	2.24
21	Bleach washer	6.4	8.6	0.96	0.56	1.12
22	Mill sewage	7.0	8.0	0.11	0.11	0.14
23	Napkin stock	6.8	8.2	0.22	0.19	0.52
24	Whitewater	7.0	8.0	0.16	0.20	0.44
25	Paper mill sewer	6.8	8.2	0.16	0.20	0.24
26	Bleached pulpwash	6.0	9.2	1.12	1.12	1.36
27	Main sewer	6.6	8.6	0.8	0.9	1.16
28	W. W. disch. to sew.	6.6	8.8	0.32	0.24	0.40
29	W. W.-Fourdrinier	7.6	8.4	0.06	0.06	0.08
30	W. W. tank overfl.	6.6	9.1	0.24	0.16	0.32
31	Main sewer	7.5	8.2	0.14	0.11	0.19

TABLE III—*Continued*

PAPER MILL WASTES. VARIATIONS IN FREE AMMONIA NITROGEN

No.	Kind of Waste	pH Variable Initial pH	pH Variable Final pH	N, P. p. m.	Phosphate Buffer Method pH = 7.4 N, P. p. m.	Na_2CO_3 Method pH Greater than 10.6 N, P. p. m.
32	Sewer from mach.	7.3	8.4	0.18	0.16	0.22
33	Knotter saveall	6.7	9.1	0.32	0.32	0.40
34	Knotter thickener	6.7	9.2	0.48	0.16	0.48
35	Machine sewer	7.4	8.4	0.19	0.11	0.20
36	Disch. to sewer	6.6	9.4	0.80	0.56	0.96
37	Main sewer	7.4	8.6	0.08	0.10	0.18
38	Main sewer	7.5	8.4	0.19	0.13	0.19
39	Machine sewer	7.4	8.5	0.27	0.29	0.32
40	Wet mach. sewer	6.8	9.2	0.42	0.48	0.56
41	Bleached W. W.	6.7	9.4	1.40	1.12	1.40
42	Machine sump	7.2	9.0	0.16	0.08	0.16
43	Machine sewer	7.6	8.6	0.32	0.27	0.32
44	Main sewer	7.4	8.8	0.27	0.18	0.30
45	W. W. overflow	7.2	9.0	0.42	0.42	0.45
46	Machine sewer	7.6	8.6	0.22	0.16	0.28
47	Sewage from mill	7.6	8.8	0.16	0.11	0.18
48	W. W. big machine	7.2	9.2	0.22	0.22	0.30
49	Pulp mill wetroom	7.2	9.2	0.40	0.16	0.20
50	Bleach plant sew.	6.8	9.6	0.48	0.32	0.40
51	Main sewer	7.4	9.2	0.18	0.16	0.21
52	W. W.-96′ cyl.	7.6	9.2	0.32	0.27	0.35
53	Mill sewage	7.8	9.1	0.11	0.08	0.16
54	Alum eff.	7.2	9.8	0.28	0.28	0.48
55	Unbleached W. W.	6.8	10.6	1.12	0.56	0.96
56	W. W. from mach.	7.4	10.6	0.20	0.16	0.20
57	Sewage from wash	9.2	9.2	0.24	0.24	0.28
58	Rag washer waste	9.0	9.4	0.16	0.16	0.20
59	W. W. from mach.	8.2	10.6	0.13	0.06	0.10
60	Felt W. W.	8.4	10.6	0.10	0.06	0.10
61	Rag washer sew.	9.2	10.6	0.56	0.24	0.32
62	De-inking sewage	9.2	10.6	1.00	0.84	1.00
63	Black sulph. liq.	10.6	10.6	170.00	140.00	160.00

Note: W. W. means white water.

Many of the results given in this table show low free ammonia nitrogen but on a percentage basis the variation between the results of the three methods is of the same magnitude as previously. While space will not permit the discussion of these results in detail, there are some outstanding cases to be noted. Values obtained from Samples 1 and 5 bring out what appears to be organic hydrolysis. In these two cases the results using sodium carbonate are far greater than those obtained with a constant pH of 7.4. Somewhat the same situation obtains with Sample 6 although it is difficult to explain why the free ammonia nitrogen, when

using no buffer, is greater than when the phosphate buffer is used. It has been found that when attempts were made to determine free ammonia nitrogen of similar acid wastes by back titration of the distillate, acid constituents were distilled over so as to completely obscure any recovery

TABLE IV

MILK AND CREAMERY WASTES. VARIATION IN FREE AMMONIA NITROGEN

No.	Kind of Waste	pH Variable Initial pH	pH Variable Final pH	N, P. p. m.	Phosphate Buffer Method, pH = 7.4 N, P. p. m.	Na_2CO_3 Method, pH Greater than 10.6 N, P. p. m.
	A. Milk Wastes					
1	Plant influent	4.8	4.8	1.6	10.0	20.0
2	Plant influent	4.8	4.8	2.0	8.0	11.0
3	Plant influent	5.0	5.6	2.8	5.6	8.0
4	Filter effluent	5.4	6.2	1.6	1.6	2.4
5	Final effluent	5.8	6.0	7.2	8.4	9.2
6	Filter effluent	5.8	6.4	10.0	12.0	14.0
7	Final effluent	6.0	6.6	14.4	20.8	20.8
8	Final effluent	6.0	7.3	16.0	20.0	20.0
9	Raw waste	5.5	8.2	6.8	7.6	10.0
10	Raw waste	5.5	8.2	1.6	2.0	4.4
11	Filter effluent	5.6	8.2	11.2	10.8	11.2
12	Can washer eff.	6.3	7.5	1.6	2.4	2.4
13	Plant sewage	5.6	8.2	7.6	8.8	50.0
14	Plant sewage	5.7	9.1	1.6	0.8	8.8
	B. Creamery Wastes					
15	Raw waste	4.6	6.8	4.4	5.6	10.4
16	Raw waste	5.1	8.0	20.8	38.0	38.0
17	Raw waste	4.8	8.6	2.8	2.8	8.8
18	Raw waste	6.2	7.8	4.0	4.4	10.8
19	Raw waste	6.6	7.6	3.8	4.0	4.2
20	Filter effluent	5.5	9.3	28.0	28.0	28.0
21	Final effluent	5.8	9.5	17.6	36.8	49.6
22	Comp. tank eff.	6.4	9.2	20.0	21.0	20.0
23	Filter influent	6.2	9.4	2.0	2.0	3.0
24	Comp. raw sewage	7.2	8.4	80.0	52.0	74.0
25	Filter influent	6.2	9.8	2.0	2.0	2.8
26	Sec. settl. tank	7.2	9.1	0.8	1.04	1.12
27	Filter effluent	7.4	9.1	1.0	0.9	1.0
28	Filter effluent	7.6	9.5	2.75	2.75	3.0
29	Sec. settl. tank	7.5	9.6	3.0	3.0	3.8
30	Filter effluent	6.8	10.6	20.0	21.6	20.0
31	Sec. settl. tank	6.8	10.6	32.0	32.0	40.0
32	Can washer eff.	8.8	8.6	0.45	0.43	1.6
33	Inf. storage tk.	10.6	10.6	1.2	1.08	1.4
34	Filter influent	10.6	10.6	2.0	1.8	3.4
35	Filter effluent	10.6	10.6	1.0	1.04	1.08
36	Storage tk. inf.	10.6	10.6	1.4	1.04	1.5
37	Filter influent	10.6	10.6	1.44	1.44	2.0
38	Filter effluent	10.6	10.6	0.84	0.8	1.0

of free ammonia. That ammonia nitrogen was present in the distillate was afterwards confirmed by nesslerization. Mason and Buswell in their "Examination of Water"[2] point out errors in certain cases in the colorimetric estimation of ammonia due to a citron green color caused by certain substances. No doubt any productive of this color would enhance the true color produced by free ammonia. It appears that this substance may be of an acidic character and that an explanation of the anomalous result obtained on Sample 6 may be due to the acidity of this sample.

In wastes from milk products the pH values are usually found to be on the acid side of the scale and in addition these wastes contain a considerable quantity of nitrogenous organic matter. Being animal wastes they are of somewhat different character from the other wastes studied, but from the comparative results shown in Table IV they offer substantial confirmation of the theory that the separation of free ammonia nitrogen from organic nitrogen is influenced considerably by the H-ion concentration of the distillation mixture. If cognizance is not taken of this factor the results obtained are so variable that interpretation is difficult.

Summary

One hundred forty-four wastes have been studied to determine the effect of the H-ion concentration of the distillation mixture on the recovery of the free ammonia nitrogen. Wastes from milk and creamery plants, beet canning factories, paper mill operations and from domestic sewage treatment are included in the study. In general, it can be said that wastes exhibiting a pH below 7.4 yield less free ammonia nitrogen than if the pH is maintained at this value by use of a phosphate buffer solution. Moreover, it is shown that these wastes give higher results, as a rule for free ammonia nitrogen if 5 cc. of a 10% solution of sodium carbonate is used as an alkalinizing agent than when the distillation mixture is maintained at a pH of 7.4 indicating, it is believed, that a certain amount of hydrolysis of organic nitrogen compounds occurs at this abnormally high pH value between 10.6 and 11.6. It appears reasonable to conclude that:

Distillation of wastes to separate the mineralized nitrogen from the organic should be conducted at a definite pH value, at or about 7.4, which is maintained constant by the use of a $M/2$ phosphate buffer solution.

References

[1] M. Starr Nichols and Marian E. Foote, "Distillation of Free Ammonia Nitrogen from Buffered Solutions," *Ind. Eng. Chem.* (*Anal. Ed.*), **3**, 311 (July 15, 1931).

[2] William P. Mason and Arthur M. Buswell, "Examination of Water, Chemical and Bacteriological," 6th Edition, John Wiley and Sons, Inc., New York; Chapman and Hall, Limited, London, 1931.

Recent Studies on Sludge Digestion*

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Advances in sludge digestion during the past year have shown a further trend toward separate digestion methods for both large and small plants. Particular attention has been given to a study of the design of digestion units to best advantage. These studies involve the question of effect of temperature control, pH adjustment, stirring, ripe sludge balance, sludge concentration, and character and quantity of material to be digested.

Former methods of figuring digester capacities on a per capita basis are now being discarded in favor of the more logical method of taking the organic load as the determining factor. It is obviously unfair to expect a tank treating all the sludge from a complete treatment system to perform the same work as a unit of the same capacity receiving only primary sludge; nor can a tank handling such materials as cannery or creamery wastes be compared with one receiving only sludge from a strictly domestic sewage.

In considering digestion capacities, it should be borne in mind that a digester has three functions: (1) to produce a relatively stable and inoffensive digested sludge; (2) to produce a clear overflow liquor of low solids content; and (3) to store digested sludge until it can be drawn onto drying beds. As a rule the natural separation of water from sludge during the process of digestion is enough to provide a sufficiently large clarification zone to allow the displacement of clear supernatant liquor, provided no other disturbing factors are present. Under no consideration, however, should sludge be accumulated in the digester to within less than one foot below the overflow pipe; otherwise, an excessive amount of finely divided solids such as are usually present at the sludge-liquor junction will be buoyed up by gas ebullition and carried over in the overflow. It is customary to take off the overflow liquor at a point about twelve to eighteen inches below the liquid level, for protection against possible scum formation. This gives a longer detention period, and insures against short-circuiting of raw sludge through the tank and out the overflow.

Under proper operating conditions a normal digester overflow liquor should not contain more than 0.30% total solids, of which about two-thirds are dissolved and one-third are suspended. The greater part of the suspended solids are readily settleable after being removed from the main body of the digester as they consist largely of small granular solid particles held in suspension by violent ebullition of gas. The volume of overflow liquor is somewhat less than the amount of raw sludge introduced. Accurate measurements at Aurora, Illinois, during an extended test period, showed

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a daily input of 880 cu. ft. of 94% raw sludge per day, while the overflow liquor amounted to 755 cu. ft. per day. This difference may be accounted for by the reduction in solids due to digestion. In a primary treatment plant handling an average domestic sewage the volume of overflow liquor will be only 0.07 to 0.15% of the total sewage flow. This small flow with its low solid content can have no detrimental effect on the subsequent treatment process when returned to the raw sewage, especially if it is well distributed over the entire day.

Factors that disturb the supernatant liquor are high and low temperatures, violent stirring, and the introduction of too dilute a raw sludge, or too large a volume of raw sludge at one time, into the digester. Observations at numerous unheated digestion plants show that invariably after the winter months, when digestion is accelerated by increasing temperature, scum production increases and the supernatant becames heavily charged with solids. This condition would be entirely eliminated if a uniform temperature were maintained all year around.

Considerable interest in thermophilic digestion has been evinced during the past year. Our experience, based on large scale tests carried out at Aurora, Illinois, showed that these high temperatures (130° F.) produced a highly putrescible overflow that would require special treatment before it could be returned to the raw sewage. Average results showed that this material contained 1500 p. p. m. suspended solids, 450 p. p. m. of which were non-settleable.

Comparative tests have shown that violent agitation in a digester causes scum formation and increases the solid content of the supernatant liquor, while gentle stirring eliminates scum and has no effect on the suspended solid content of the overflow.

Observations at numerous plants show that the pumping of too large a volume of sludge at one time increases the putrescibility of the overflow, and tends to set up a condition in the digester somewhat similar to the effect of violent agitation, where the sharp line between sludge and supernatant is destroyed, and the latter becomes a thin sludge of one to two per cent solids. This condition is often met with where waste activated sludge is pumped directly into the digester instead of being first concentrated, such as by returning it to the primary settling tank.

In order to utilize the effective digestion capacity, *i. e.*, the capacity below the clarification zone, to best advantage, it is necessary to digest the raw sludge as quickly as possible and to secure the maximum average sludge density.

It is now generally recognized that sludge heating is highly beneficial, even in the more temperate climates. Recent plant studies show that the rate of digestion increases with temperature up to about 100° F., after which there is a lag, until the thermophilic range is reached. A number of

plants now hold a temperature of 90° to 95° instead of 75° to 80° F., which was formerly thought to be the optimum.

Large scale tests on digestion at 130° F. as compared with 90° F. digestion have failed to show a more rapid rate of digestion, or greater gas production at the higher temperature. On the other hand, 130° F. digestion gave unfavorable results in that it caused scum formation, increased the hydrogen sulphide content of the gas, and produced a digested sludge that was difficult to dewater.

Addition of lime for pH value adjustment now has a recognized place for correcting sludge acidity, especially where a tank is being put into operation. After digestion is once established in a heated tank, however, lime additions are rarely required because of the alkaline nature and buffer action of the seeding sludge. Where certain organic wastes, such as from creameries and canneries, enter a plant, a frequent check on the pH value of the sludge is advisable, as these materials tend to form organic acids which inhibit gas production and cause liquefaction. As a rule, when digestion is well established the pH value of the sludge varies from 6.8 to 8.0.

Stirring, whether slow or rapid, aids digestion because of its action in intimately mixing the raw and digested sludge. Rapid stirring, however, has the disadvantage that it causes the sludge to bulk and so reduces the effective depth of the digester. Records show that stirring increases the gas production from ten to thirty per cent. It has been argued that this increase is due almost entirely to carbon dioxide. Tests have shown that this is not the case after digestion is well established. Gas analyses at a number of plants having slow stirring show a carbon dioxide content of from twenty-five to thirty per cent, depending on the nature of the sludge.

The question of the amount of ripe sludge required for seeding has become of greater importance in view of the recent studies on the use of sludge storage tanks, stage digestion and continuous sludge dewatering methods. Formerly a 40:1 ratio (*i. e.*, 40 pounds of ripe sludge volatile solids for each pound of raw sludge volatile solids added daily) was considered necessary at 70° F. This was later reduced to 20:1, when temperature and pH value control was employed. The latter is the equivalent of about a thirty to thirty-five day digestion period. At Aurora it was demonstrated that a satisfactory digested sludge could be obtained continuously in twelve days at 90° F. A constant ratio of eight parts ripe to one part raw volatile solids was maintained during the test.

The concentration of raw sludge ahead of digestion is now being given considerable attention with the idea of cutting down heat losses, reducing the volume of overflow liquor, and increasing the average sludge density in the digester. Laboratory tests have shown that concentration of the raw sludge to 18 per cent solids has very little effect on the digestion rate. Indications are that high concentrations may be obtained by the use of

auxiliary thickeners, or decanting tanks, especially in the colder climates where the sludge will not become septic within two or three days.

Sludge storage capacity to take care of five to six months' accumulation of digested sludge is now being provided at some of the larger plants in separate unheated tanks. The system in operation at Grand Rapids is typical of this type of installation. It has the advantage that digested sludge is withdrawn at the same time that raw sludge is introduced. This system may reduce the volume of overflow liquor to less than 35 per cent of the volume of raw sludge pumped each day.

Developments indicate that continuous methods of disposal of solids, such as by means of vacuum filters, should in many cases eventually eliminate sludge storage space and drying beds. Continuous removal and disposal of solids, together with temperature control at 90° F., raw sludge concentration to about 15 per cent solids, gentle stirring, and pH value adjustment to about 7.0 when required, should give satisfactory digestion with an effective capacity of less than 5.0 cu. ft. per pound of volatile solids added per day. For an average domestic sewage containing 200 p. p. m. suspended solids this is equivalent to 0.56 cu. ft. per capita for a complete treatment plant removing 90 per cent of the suspended solids.

Sewage Works Operation

Some Notes on the Operation of Sewage Treatment Works*

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Happily the art of sewage treatment in this country seems to be reaching a point where a James Whitcomb Riley will soon be needed to immortalize the passing of the old style municipal treatment works, or as it was ineptly termed, "the disposal plant." These older plants, characterized by the absence of any pretentious superstructure, need little description. They were generally located in some forsaken ravine, the exact locality being identified by a vast growth of weeds or perhaps by the sense of smell. Few citizens were able to direct a visitor to the works and frequently the officials at the city hall had only a vague knowledge as to the existence of sewage treatment facilities. In many cases troubles with these neglected plants were due not to inadequacy of design for the intended purpose, but to a lack of knowledge of the capabilities of the processes, and a lack of appreciation by the local authorities of the need for operating the works in a competent manner.

There has been in late years a quite rapid development of civic consciousness toward the adequate handling of liquid and other wastes of the municipality, a greater willingness to support necessary expenditures at the back door of the city and in many cases the development of a surprising degree of civic pride in sewage treatment undertakings, both as to structures and performance.

One factor in improvement of the sewage treatment situation is the increasing tendency to use mechanical appliances in place of the more laborious hand methods formerly in vogue. The installation of mechanical appliances has led to more pretentious superstructures and has also led naturally to a better quality of attendance in the management of these devices. With the improvement in plant facilities and grounds, there has come a disposition to compensate more fairly the men who operate these works. This trend is inviting into the sewage disposal field men with better training and more ambition.

There is still much to be done toward stabilizing the position of plant operators so that they may feel reasonably secure from political turn-overs.

* *Presented before the North Carolina Sewage Works Association, Greensboro, N. C., Nov. 3, 1931.*

The speaker favors very strongly the policy of licensing the sewage plant operator by the State Board of Health after an examination based on requirements of the particular set of circumstances which the operator would be called upon to face, in other words by grades of license. Such a licensing system has the effect of placing qualified men in charge of operation and preventing their removal for reasons other than incompetency and neglect of duty.

We in America may be very proud of the important research studies carried out on sewage and sewage treatment at various points in the country within the last five or six years. The results of this fundamental work are being reflected in recent plant designs and in improved results of treatment by the older and better known processes. It is well to take cognizance also of the very interesting experimental work now being carried on at widely distributed localities with more direct methods, in the effort to secure clarification and reduction of organic matter by the use of paper pulp with or without lime and coagulants, followed by filtration in some form. These processes are aimed at elimination of the digestion and sludge disposal methods now commonly employed, and are also intended to reduce the time requirement for purification.

Before discussing some problems of plant operation, the author wishes to acknowledge the value of contributions to the art of sewage treatment by the North Carolina group. Particularly helpful had been the recent paper by Mr. McConnell as published in the *Engineering News-Record* of Aug. 13, 1931 (Vol. 107, p. 247) which embodies the operating data and experience of the two Charlotte plants. Seldom are such detailed data available in published reports, especially as to itemized cost.

Probably there is more current interest in the activated-sludge process than any other well established type of treatment, and for that reason some notes on the operation of a small activated-sludge plant are first offered for discussion.

Tenafly, N. J., is a residential suburb of New York City, with a population of some 6000, of which 5200 to 5300 are now connected with sewers. A separate sewer system and treatment works were put in service Feb. 24, 1928, replacing disposal by cesspools.

The sewage treatment is by the activated-sludge process, designed for a population of 7500 and a flow of 750,000 gallons daily. The actual flow during the dry summer months ranges from 315,000 to 400,000 gallons daily. During the winter and early spring the flow for weeks at a time ranges from 450,000 to 550,000 gallons. During extreme rainfall conditions when the streets were flooded, the flow has reached a peak of 1,000,000 gallons for short periods.

The sewage is delivered by gravity to the plant, thence passes through a Link-Belt screen with $^1/_{16}$-inch slots. Pumps then raise the screened

sewage to two spiral-flow aeration tanks, each 12 feet wide, by 86 feet long and 10 feet flow-line depth, having a combined holding capacity of approximately 150,000 gallons. The aerated sewage is settled in two Dorr clarifiers, each 20 feet by 20 feet in plan with flow-line depth of 10.25 feet to the sloped bottom. The clarifier effluent flows to a dosing chamber serving 5 intermittent sand filters having an aggregate area of 1.5 acres. Chlorination of the sand filter effluent in a special detention chamber before delivery into Tenakill Creek completes the treatment.

The special feature of note in connection with the Tenafly plant is the existence of intermittent sand filters between the clarifiers and the creek. Tenakill Creek, which receives the final effluent, is an important feeder to the Oradell Reservoir of the Hackensack Water Company hence no precautions have been omitted to secure the highest degree of sewage treatment.

The final effluent has with few exceptions been uniformly excellent as judged by physical, bacterial and chemical standards. The difficulties of operation here mentioned are related to the behavior of aeration tanks and clarifiers whereby suspended solids in troublesome amounts have escaped at times over the clarifier weirs, thus causing considerable annoyance and expense for frequent cleaning of the sand filters. These difficulties became particularly acute during the winter of 1930–31, when freezing weather added complications to the problem of keeping the filters clean. The plant was brought back to a satisfactory operating basis early in the spring of 1931 and has remained so to date. The observations during this six months' period, since they cover the speaker's more intimate contact with the plant and more complete records, may be of interest to others dealing with small activated-sludge installations.

In Table I are given the daily weighings of suspended solids in the clarifier effluent, based on composite samples.

The average results for the several months are quite in line with the usual performance of the process elsewhere, but a question naturally arises as to the inconsistency of the daily results. In other words, why does the process give remarkably fine results for a period of one or two weeks and then suddenly show peaks of high solids. The answer, of course, is sludge bulking, a phenomenon quite commonly reported with the activated-sludge process. Although some indications of bulking may be had in advance, the actual lifting of the sludge blanket in the clarifier to the point of spilling high solids over the weirs is an occurrence of surprisingly short duration, a matter of a few hours, occurring nearly always in the late afternoon.

Much speculation has been made as to the cause of sludge bulking, and the subject yet needs very careful research study to reconcile the experience at various localities.

Speaking of Tenafly conditions only, it has been the observation that

bulking is always accompanied by an increased or profuse growth of *Sphaerotilus*, a filamentous bacterium. When the flocculent sludge becomes permeated with these thread-like organisms, the sludge cannot be properly consolidated in the clarifiers. The action may be likened to the impossibility of getting a dense sludge by settling cotton fibers in a liquid medium.

A similar association of *Sphaerotilus* with sludge bulking has been reported at a number of places both in this country and in England, The experience at the Des Plaines River plant of the Chicago Sanitary District as reported by Messrs. Morgan and Beck and a detailed study of the organism involved as reported by Messrs. Ruchhoft and Watkins, all in the

TABLE I

AVERAGE SUSPENDED SOLIDS PASSING OVER CLARIFIER WEIRS IN PARTS PER MILLION

Day	May	June	July	Aug.	Sept.	Oct.
1	22	39	19	22*	17	17
2	30	11	12	13	23	5
3	83	16	7	28	6*	2
4	49	12*	11	26	25	3
5	25*	16*	10	15	10	7
6	22	19	6	16	4	4
7	21	4	5	36*	6	5
8	25	7	4	28	61*	5
9	22	6	4	20*	106*	3
10	15	9	10	27*	90*	7
11	22	14	15	28*	63*	9
12	31	21*	3	17	4*	5
13	73	15	7	76*	87*	20*
14	39	32	14	162	..*	19*
15	37*	90	23*	45*	16	11
16	13	53	9	15*	17	7
17	..	26*	7	9	11	9*
18	25	13*	34*	7	12	25*
19	13	10	15	3	14	10
20	16	18	13	3	13*	7
21	26*	34	5	2*	14*	10
22	18	19*	5	5	3	12
23	7	7*	5	4*	7	7
24	18	14	5	9	5	7*
25	2	12	6*	9	20*	25*
26	3	12*	13*	9*	3*	30
27	6	6	18	10	3	25
28	5	3	16*	5	7	5
29	9*	12	17	32	4	4
30	29	8	10	7*	4	7
31	8	..	11	15	..	5
Av.	23	19	11	23	23	10

* Dates of lime application to aeration tanks.

1929 SEWAGE WORKS JOURNAL (Vol. I, pages 46 to 58), were fresh in mind when the Tenafly operation began to be studied carefully and it was supposed that the Tenafly situation was a duplication of the one at Des Plaines, hence studies of sugar wastes on the incoming sewage were undertaken. It was, as a matter of fact, established that a surreptitious commercial still was in operation in the district during the time that the troubles began to be acute. However, later observations, after all reasonable clues of this nature were exhausted, have led the speaker to believe that carbohydrate wastes and other organic substances derived from alcoholic distillation are not necessarily selectively stimulating to *Sphaerotilus* growth. It is probable that carbohydrate wastes having a high oxygen demand act simply as an added load on the purification plant, in much the same manner as would a greatly increased population or the addition of many other substances having a high B. O. D. It is possible that the changing habits of a considerable number of our people in these Volstead days may cause us to revise our assumptions as to the absence of trade wastes from domestic sewage and may cause us to take cognizance of the increased organic loadings on treatment processes, particularly activated sludge.

The environmental conditions which permit the rapid growth of *Sphaerotilus* are being studied by the U. S. Public Health Service and others. When the results of these studies are made known we will have a much better understanding of bulking than at present. *Sphaerotilus*, it should be remembered, is the usual fungoid growth occurring on submerged objects in streams containing sewage pollution and in localities where one would not expect undue amounts of carbohydrate wastes. The later disappearance of *Sphaerotilus* growths further downstream from the point of pollution suggests very strongly that some component of decomposing sewage, which is attractive to the organism, later disappears as purification progresses. At least some practical use has been made of this hypothesis in tracing out the causes of occasional peaks of high solids over the clarifier weirs. The theoretical aeration time in the Tenafly plant is from 4.5 to 10 hours, based on sewage flow plus return sludge. Actually, however, it is found that lime added to the inlet of the tanks appears in the tank effluent within two hours. This observation leads to the thought that spiral-flow tanks may short-circuit more than has been supposed and that the appearance of *Sphaerotilus* may be related to "leaks" of organic matter which have not been in contact with the activated sludge a sufficiently long time for adequate purification, in spite of ample air supply.

Available means for controlling bulking have a very practical interest. The use of coagulant to weight the sludge in the clarifiers has not been found of any value but the use of lime has proven an effective remedy when applied at the proper time and in the proper manner. In the Des Plaines papers noted above the benefits from the use of lime were noted, also the

observation that no growths of *Sphaerotilus* occur in artificial culture media having a reaction greater than pH 8.8. Both of these observations are confirmed by Tenafly experiences. At the first indications of bulking as shown by the sludge condition index or by raising of the sludge blanket in the clarifier, hydrated lime is fed for a period of 6 to 12 hours in dosage sufficient to maintain a reaction of pH 8.6 to 8.8. The lime is applied at the inlet of the aeration tank and the control pH tests are made at the outlet of the tanks. Too little lime does no good and too much lime results in an

TABLE II

OPERATING RESULTS—TENAFLY, N. J.
July, 1931

Days	% Solids in Aeration Tank Volume, 30 Min.	% Solids in Aeration Tank Susp. Sol. by Weight	Solids in Return Sludge, %	Sludge Index	Air, Cu. Ft. per Gal.	Aer. Time, Hrs.	Dissolved Oxygen, P. p. m. A.M.	Dissolved Oxygen, P. p. m. P.M.
1	19	0.24	2.44	1.26	1.36	7.5	...	...
2	19	0.20	1.68	1.05	1.53	8.0	...	...
3	25	0.26	1.78	1.04	1.28	7.0	...	...
4	19	0.23	2.10	1.21	1.26	7.5	...	...
5	22	0.25	1.78	1.14	1.32	7.5	...	...
6	21	0.20	2.10	0.95	1.26	7.0	0.6	2.4
7	20	0.19	2.50	0.95	1.22	7.7	3.7	2.4
8	22	0.19	2.34	0.86	1.24	7.5	1.8	2.2
9	20	0.19	1.82	0.95	1.32	7.5	2.9	1.3
10	23	0.17	2.04	0.74	1.27	7.5	3.1	2.4
11	21	0.20	2.22	0.95	1.28	7.3	3.3	2.1
12	22	0.17	1.80	0.77	1.22	8.0	3.0	0.8
13	18	0.17	1.72	0.95	1.16	7.0	4.5	0.6
14	18	0.20	2.24	1.11	1.43	8.0	1.6	1.0
15	17	0.18	1.88	1.06	1.48	8.0	2.3	..
16	15	0.21	2.30	1.50	1.54	8.5	2.5	1.8
17	21	0.17	1.96	0.81	1.62	8.5	2.7	1.0
18	19	0.14	1.28	0.73	1.62	8.7	3.3	1.7
19	18	0.21	2.24	1.17	1.62	9.0	...	0.8
20	19	0.20	2.54	1.05	1.46	8.2	1.5	0.3
21	20	0.20	2.40	1.00	1.32	7.7	1.5	0.3
22	17	0.20	2.26	1.17	1.32	7.0	1.6	0.8
23	16	0.20	2.46	1.25	1.46	8.3	1.0	0.3
24	15	0.20	2.18	1.33	1.52	8.5	1.2	0.3
25	15	0.17	1.84	1.13	1.60	9.0	1.8	0.5
26	16	0.14	1.40	0.88	1.85	9.8	...	0.4
27	16	0.15	2.04	0.94	1.78	9.8	...	...
28	19	0.17	2.52	0.90	1.77	10.0	2.0	0.7
29	20	0.16	1.80	0.80	1.72	9.5	2.2	0.9
30	16	0.17	2.04	1.06	1.52	7.4	1.6	0.3
31	18	0.15	1.66	0.83	1.72	5.6	1.0	0.3
Av.	19	0.19	2.06	1.01	1.45	8.2	1.6	0.85

$$\text{Sludge Index} = \frac{\%\ \text{Suspended Solids in Aeration Tank by Weight} \times 100}{\%\ \text{Sludge Volume in Aeration Tank, settled 30 Min.}}$$

TABLE II (*Continued*)

OPERATING RESULTS—TENAFLY, N. J.

August, 1931

Days	% Solids in Aeration Tank Volume, 30 Min.	% Solids in Aeration Tank Susp. Sol. by Weight	Solids in Return Sludge, %	Sludge Index	Air, Cu. Ft. per Gal.	Aer. Time, Hrs.	Dissolved Oxygen, P. p m. A.M.	Dissolved Oxygen, P. p m. P.M.
1	26	0.18	2.66	0.69	1.48	4.5	0.4	0.2
2	15	0.19	2.54	1.27	1.96	5.5	...	...
3	20	0.20	1.96	1.00	1.33	4.5	...	0.4
4	18	0.21	2.14	1.17	1.72	9.0	...	...
5	23	0.23	1.84	1.00	1.55	9.0	2.8	1.0
6	30	0.20	1.44	0.67	1.87	9.0	3.1	1.2
7	25	0.17	1.34	0.68	1.55	7.5	2.0	0.3
8	31	0.20	1.48	0.65	1.72	8.5	2.4	0.3
9	25	0.20	1.20	0.80	1.50	7.5	...	...
10	21	0.22	1.32	1.05	1.38	7.3	1.2	0.0
11	19	0.27	2.44	1.42	1.41	7.2	1.0	0.8
12	17	0.23	2.30	1.35	1.48	7.5	2.5	0.6
13	18	0.20	1.92	1.11	1.57	8.2	2.4	0.7
14	24	0.19	1.02	0.79	1.46	7.0	1.2	1.0
15	25	0.19	0.66	0.76	1.47	6.7	...	0.8
16	11	0.23	2.04	2.08	1.43	7.2	...	0.3
17	14	0.23	1.64	1.64	1.43	7.0	3.5	0.4
18	19	0.27	1.96	1.42	1.46	7.5	2.1	0.2
19	23	0.25	1.58	1.09	1.13	6.0	1.8	0.5
20	27	0.24	1.20	0.89	1.34	6.3	2.3	...
21	29	0.28	1.42	0.97	1.40	6.1	2.1	0.8
22	24	0.28	1.20	1.17	1.49	6.5	2.8	0.5
23	31	0.29	1.36	0.94	1.50	6.3	2.4	0.5
24	28	0.28	1.16	1.00	1.35	6.4	2.3	0.3
25	31	0.29	1.10	0.94	1.46	6.1	3.0	0.2
26	27	0.28	1.16	1.04	1.49	6.5	2.5	0.3
27	23	0.29	1.72	1.26	1.53	7.1	2.7	0.4
28	25	0.29	1.56	1.16	1.50	7.1	2.4	1.3
29	23	0.21	1.38	0.92	1.56	7.5	0.8	...
30	27	0.23	1.32	0.85	1.52	7.0	...	0.5
31	37	0.26	1.16	0.70	1.53	6.6	2.0	0.3
Av.	24	0.23	1.59	1.05	1.50	7.0	2.1	0.53

$$\text{Sludge Index} = \frac{\%\ \text{Suspended Solids in Aeration Tank by Weight} \times 100}{\%\ \text{Sludge Volume in Aeration Tank, after Settling 30 Min.}}$$

impairment of clarification. In Table I the asterisks mark the dates on which lime application was made. On some occasions lime was not applied early enough or in sufficient amounts to control the situation. Applications of lime at inlet of clarifiers, though more economical, have not given as good results as at inlet of aeration tanks.

The principal change in the operation of the Tenafly plant which improved conditions over those of last winter has been the reduction of solids carried in the aeration tanks. During the first year of operation very good

TABLE II (*Continued*)

OPERATING RESULTS—TENAFLY, N. J.

September, 1931

Days	% Solids in Aeration Tank Volume, 30 Min.	% Solids in Aeration Tank Susp. Sol. by Weight	Solids in Return Sludge, %	Sludge Index	Air, Cu. Ft. per Gal.	Aer. Time, Hrs.	Dissolved Oxygen, A.M.	Dissolved P. p. m. P.M.
1	40	0.25	0.76	0.63	1.61	6.1	2.0	0.3
2	33	0.23	0.64	0.70	1.48	5.5	2.2	0.3
3	43	0.21	0.82	0.49	1.70	6.5	2.2	...
4	36	0.21	0.64	0.58	1.48	5.5	2.1	0.3
5	44	0.21	1.00	0.48	1.55	6.5	...	...
6	49	0.19	0.68	0.39	1.61	6.5	...	...
7	65	0.19	0.72	0.29	1.62	6.8	...	...
8	64	0.20	0.60	0.31	1.60	6.0	2.2	0.5
9	57	0.19	0.64	0.33	1.69	6.5	1.6	0.5
10	62	0.17	0.44	0.28	1.67	6.9	1.4	0.2
11	40	0.17	0.56	0.43	1.77	6.6	1.2	0.2
12	45	0.22	0.92	0.49	1.87	7.9	0.7	0.9
13	57	0.22	0.80	0.39	2.16	8.8	...	...
14	42	0.22	0.86	0.52	1.87	7.7	0.8	0.0
15	46	0.36	1.34	0.78	1.60	6.8	0.8	0.2
16	53	0.33	1.32	0.62	1.60	6.8	1.0	0.2
17	49	0.29	1.80	0.60	1.58	8.0	1.6	0.4
18	61	0.31	1.68	0.51	1.44	7.5	0.9	0.3
19	68	0.32	1.58	0.47	1.63	7.5	0.8	0.5
20	74	0.31	1.22	0.42	1.72	7.3	...	...
21	48	0.35	1.40	0.73	1.68	7.0	0.8	0.2
22	49	0.39	1.30	0.80	1.68	6.5	0.5	0.0
23	48	0.37	1.14	0.77	1.77	6.5	0.5	0.1
24	47	0.36	1.14	0.77	1.90	7.0	0.5	...
25	50	0.34	1.04	0.68	1.98	7.1	1.1	0.2
26	43	0.35	0.90	0.82	1.70	6.0	0.9	0.2
27	37	0.32	1.30	0.87	1.80	7.5	...	...
28	38	0.29	0.88	0.76	1.77	6.4	0.9	0.3
29	41	0.28	1.04	0.68	1.90	7.0	1.0	0.2
30	41	0.28	0.88	0.67	1.93	7.2	1.2	0.3
Av.	49	0.27	1.00	0.58	1.71	6.9	0.96	0.21

results were obtained with 0.7% dry solids in the aeration tank. The best operating figure now appears to lie between 0.20 and 0.25% dry solids. Under existing plant conditions dissolved oxygen cannot be maintained at the end of the aeration tanks with solids higher than 0.30%, which agrees with the experience of Mr. McConnell at Charlotte. The lower limit of solids that can be carried in the aeration tanks at Tenafly without causing loss of clarification has not been definitely determined because the disposal of the excess sludge on sand beds controls the lower limit.

To give a better idea of the recent operating characteristics of the plant the results for the months of July, August and September, 1931, are shown in Table II.

The "Sludge Index" heading the fifth column of Table II is a term used in the speaker's organization to express the quality or condition of sludge as to bulking. Wagenhals, Theriault and Hommon in the well known *Bulletin* No. 132 (pp. 22–25) of the U. S. Public Health Service, called attention to the need of combining in a single expression both the weight and settling volume of activated sludge. Their "Sludge Ratio" on basis of 30 minute settling, if divided by 10 is identical with the "Sludge Index" shown in Table II. The speaker prefers the "Index" expression, because the per cent dry solids, easily determined by the average operator, by evaporating and weighing a 50 cc. sample may be substituted with little error for the suspended solids, and serves the same purpose of indicating bulking. A Sludge Index less than 1.0 in general, indicates an undesirable condition. At Tenafly an index figure in excess of 2.0 has seldom been encountered and a figure of 4.4, such as reported at Houston (*Public Health Bulletin* No. 132, p. 24) has never been reached.

In considering the somewhat delicate balance of sludge solids in relation to aeration time, it should be borne in mind that in a small community the flow and strength of sewage peak up remarkably during the daylight hours and show a far greater departure from average flows and average strengths than is noted for plants of larger communities. This means that with a smaller plant the major portion of purification has to be effected during a smaller number of hours of the day than is the case with the larger plant.

It is of interest to record here that as a result of the studies made of the operation during the past six months, provision is now being made to install transverse baffles, similar to those at Pasadena, in the aeration tanks, to make the actual detention period agree more closely with the theoretical detention period and thereby get away from the effects of short circuiting. There is also being installed a tank for reaeration of the return sludge, which tank will have a volume of about 20 per cent of that of the aeration tanks. The purposes of this reaeration tank are to secure full activation of the return sludge, to provide a balancing arrangement for meeting the inequalities of organic load in the raw sewage as between night and day, and to give better protection against unexpected dumping of surreptitious non-domestic wastes.

Although the causes and prevention of sludge bulking above described have been the subjects of chief interest in connection with the Tenafly operation, there are, however, some other operating features which may be touched upon.

The handling of the excess activated sludge on covered sand beds was fully described by the speaker and Mr. Kurtz in the 1929 SEWAGE WORKS JOURNAL, Vol. I, page 333. At that time the excess sludge was dewatered on sand beds without the use of a conditioning agent, although the possible

use of a conditioning agent was mentioned in connection with erection of a 5000 gallon steel tank for holding and measuring the excess sludge. With increase of sewer connections and population served, the ability of the covered sand beds to take care of the excess sludge became taxed, so that it was necessary to mix a conditioning agent with the excess sludge prior to discharge on the beds. After considerable experimentation with ferric chloride and aluminum sulphate the practice has now settled down to the use of the latter as an aid to the rapid dewatering of sludge on the sand beds. From 5 to 7 lb. of ordinary filter alum are added to a thousand gallons of excess activated sludge, according to the density of the sludge which has varied from 0.6 to 1.5% dry solids.

The alum has the effect of coagulating the sludge which is then dosed on the beds in batches of 2000 to 2500 gallons per bed. Each of the sludge beds has an area of 936 sq. ft., hence the applied rate of dosing is 2.1 to 2.7 gallons per sq. ft. of sand surface. The September, 1931, records show an average of 9000 gallons of excess sludge handled per day on the sand beds. During this month the average weight of dry solids in the sludge before the conditioning agent was added was 1.05%, which corrected for dissolved solids in the filtrate gave an average yield of nearly 660 lbs. of dry suspended solids handled on the beds each day.

The sludge dewaters quickly and is usually removed as a moist cake within 18 to 30 hours after dosing. During the hot weather of last summer, the excessively high temperatures in the glass-covered drying house caused some odors to develop both in the drying house and on the dump where the sludge was disposed of, particularly with sludge conditioned with ferric chloride. To avoid putrefactive changes the practice was adopted of adding to the sludge in the conditioning tank before discharge on the beds a small amount of copper sulphate, from 1 to 2 lbs. per thousand gallons of sludge. This has served the purpose excellently and no odors have since occurred either during the drying on the beds or on the sludge dump. However, a light cover of earth is sprinkled over the fresh sludge dumpings daily in order to remove the possibilities of offense.

Another somewhat unusual feature of the Tenafly plant is the disposal of material from the fine screens. The screenings are delivered automatically into an ejector from which they are discharged once or twice a day into one of three compost cells, which are merely concrete bins having good underdrains and covers to exclude sunlight. With these two primary conditions of good drainage and darkness, the composting idea has proved to be very satisfactory for a small plant, being free from odors and flies. The compost cells are used in rotation, the material in the idle cells shrinking in volume quite rapidly due to decomposition through the agency of molds. The cells are cleaned about once a year and without any particular offense. The composted screenings have heretofore been buried in trenches but attempt

will be made this year to make a mulch between alternate layers of soil and thus completely destroy the organic matter and secure a useful product.

Leaving behind the Tenafly problems which have recently been of chief interest to me, brief mention will be made of a few of the operating problems of other plants with which I am familiar.

The operator of the Middletown, N. Y., plant happened to look out of the window last year and was amazed to see his settling tanks in flames. Obviously there had been a discharge of volatile oils, such as cleaning naphtha into the sewers and it became ignited in some unknown manner and burned on the tanks for something like an hour and a half. No particular damage was done but this instance will serve as an illustration of the present-day hazards of operating sewage plants. At one of the New Jersey works not long since, a match tossed casually into a settling tank inside a building had results far more disastrous than those at Middletown. The speaker just recently visited another plant where the dumping of cleaning naphtha in large quantities is done once or twice a week and collects in a thick layer on the grit chambers and tanks. A dipper full of this light oil thrown on a pile of dirt ignited readily and burned for some twenty or thirty minutes, showing very clearly the potential dangers in wastes of this kind if accidentally ignited in enclosed structures, such as sewers, screen chambers or pump wells.

There is an interesting situation in sludge handling at the New Haven sewage treatment works, which comprise coarse mechanical screens, a mechanical detritor, clarifiers and chlorination, the latter during the summer season only. Primary sludge from the three Dorr settling units is pumped daily to elevated steel storage tanks located on the pierhead. After each pumping to the storage tanks, the sludge is allowed to settle and the supernatant is decanted to the inlet of one of the clarifiers. Daily pumping and decantations are carried out until sufficient accumulation of sludge is on hand to justify barging to sea. The sludge as pumped from the clarifiers to the storage tanks has averaged about 2.43% dry solids, while the sludge delivered from the storage tanks to the barge has averaged about 13.5% according to the operating records, thus reducing very materially the quantity of sludge sent to sea. The sludge barge, which is a converted oil scow having four covered steel tanks, makes trips for dumping sludge at intervals of 7 to 15 days, carrying a cargo of wet sludge containing an average of about 31 tons, dry solids basis. The interesting part of this procedure is that the primary sludge from settling tanks has been stored in these elevated steel tanks during the hot summer months for considerable periods without any complaint as to odors. When the New Haven plant was projected, it was anticipated that it might be necessary to use some chemical such as copper sulphate or chlorine in the stored sludge to defer putrefactive changes, but this has not been found necessary. The odor

from the stored solids is, of course, noticeable locally when transferring the sludge from storage tank to barge but the odor is localized and of short duration.

The ease with which the fresh sludge may be consolidated in storage tanks suggests the utility of similar decantation methods in connection with separate sludge-digestion plants where the difficulty of maintaining digestion temperatures at the optimum point is due to the large amount of water handled with the sludge entering the digester and the equivalent amount leaving as supernatant liquor. In taking advantage, however, of an intermediate decantation stage between clarifiers and digestion tanks, reasonable precaution must be exercised with retention time in order to avoid too great acidity of the sludge entering the digester. Fortunately the need of delivering dense sludge to the digesters is greatest in winter time when changes in sludge by storage are least apt to occur.

What Are Offensive Odors about a Sewage Works?*

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The word sewage is immediately suggestive of foul odor. The Greek philosopher, Theophrastus, in his treatise concerning odors, states that "anything which is decomposing has an evil odor," and modern lay opinion, in general, affirms this ancient conclusion. Folklore, if not actual experience, brings to mind the stifling privy which is rapidly giving way to the water carriage system. In the development of sewerage works, however, the modern treatment plant has had rather ill-smelling antecedents. The overflowing cesspool in the back yard, the putrid creek flowing through the town, the overloaded, neglected, and weed-grown disposal plants of former times, and unfortunately too frequently of the present also, have made such an impression upon the public mind that it is difficult to conjecture anything connected with domestic wastes apart from offensive odors. It is possibly for this reason that complaint of objectionable odors in connection with sewage disposal is as old as the art itself.

In this paper, for which free use has been made of available literature on odors, an attempt will be made to describe what the sense of smell is, how odors are classified and measured, and some of their habits; to discuss the relation of odors to public health, factors affecting odor intensity, the results of odors, the sources of odors about a sewage works and methods for their prevention and control. A suggestion will be given as to just what constitutes an offensive odor, and an opinion ventured as to whether or not a sewage plant can be operated and maintained free from nuisance.

The Sense of Smell.—An odor is perceived by the stimulation or excitation of nerve cells in a small area, less than that of a one cent piece, located near the upper end of the nasal duct. This area is somewhat protected from the direct passage of air, which accounts for the fact that one must sniff to get full benefit of an odor. There is connection also from the mouth to the olfactory area, which accounts for the theory that things we think we taste we really smell, hence the idea one can take castor oil and not taste it, by pinching the nose.

The exact mechanism of olfaction is still uncertain and although preponderance of opinion is to the effect that it is essentially a chemical process, some scientists claim that odor is the response of the olfactory nerves to inter-molecular vibrations. According to one theory, the whole question of odor depends upon three factors: Intensity, quality and olfactory sense. Before a substance, either solid, colloidal, liquid or gaseous,

* *Presented before the North Carolina Sewage Works Association, Greensboro, N. C., Nov. 3, 1931.*

can be detected by the organs of smell, it must actually come in contact with the nasal membranes, and the degree to which it does so determines the intensity of the odor. Having reached the nasal membranes the substance will then set up a chemical action with the lipinous fluid contained therein, and this chemical action determines the quality of the odor. It, therefore, becomes obvious, that if the chemical action or force of molecular interchange is great, the quantity of substance small, and widely diffused into the air, the rate of chemical action will be slow and the effect upon the nerve centers will be correspondingly slight. On the other hand, if the quantity of substance is great, but the force of molecular change small, the odor of a substance might be quite characteristic but not powerful. Lastly, if both force of molecular interchange and quantity of substance are great, the effect is likely to be prostrating as may be demonstrated by ammonia. The whole basis of the "lipin theory" is that anything which causes violent or rapid reactions with lipin is pungent or unpleasant, and anything which causes no reaction is odorless, with a graduated scale between the two extremes.

Classification and Measurement of Odors.—There is, as yet, no science of smell as there is of sound and light. No certain means have been devised whereby the character and intensity of an odor may be catalogued. Many attempts have been made to do this, but as yet these efforts have, to say the best, been only partially successful. Theophrastus divided odors into two general classes, good and evil. A more recent scientist has suggested that all odors are either dissolved or diffused.

The several systems of classification follow, in general, that of Hennig, who divides odors into six fundamental classes, as follows:

1. Spicy odors, such as those of fennel, sassafras oil, anise and cloves.
2. Flowery odors, such as those of heliotrope, cumarin and geranium oil.
3. Fruity odors, such as those of oil of orange, citronella, oil of bergamot and acetic ether.
4. Resinous or balsamic odors, such as those of turpentine, Canada balsam and eucalyptus oil.
5. Burnt odors, such as those of tar and pyridine.
6. Foul odors, such as those of carbon bisulphide and of hydrogen sulphide.

Another classification proposed by Linne, runs as follows: Aromatic, fragrant, ambrosial, alliaceous, goaty, repulsive, nauseating. To make these classes more definite, certain types of odors are attached to each main division. Thus, under "goaty" Linne would include the odors of "cheese, cat's urine and rancid oil."

A classification based on subjective judgment is inadequate and unsatisfactory. Realizing this, years ago Dr. Septimus Piesse attempted to

classify smells into a system of scales and octaves. He set out a series of odors in parallel with a musical scale and showed how it was possible to make a bouquet correspond to a chord. Perfumers thus speak of a gamut of odors, placing the name of the odor in a position corresponding to its effect upon the olfactory sense, in the order of the amplitude of vibration. According to Dr. Piesse's ingenious arrangement, at the lower end of the scale the note B corresponds with clove, while the octave B above gives stocks and pinks, and the higher octave B, cinnamon. The keen sense of smell will recognize a similarity of odors here just as the musician recognizes the repetition of a note in octaves.

The above excerpt from the *Scientific American* is given to illustrate one line of research to establish a classification of odors which will be definite and capable of general use.

Not only is it difficult to place odors into definite classes, but it is equally troublesome to establish the intensity or degree of odor within the several classifications. If odors were simple this might be possible, but the odors which usually assail us are generally mixed and hence more confusing.

At the present time exact measurement can only be made of odors that consist of substances of known chemical composition. These odors can be accurately measured whether they are dissolved or diffused.

A few years ago the laboratories of A. D. Little, Incorporated, devised a system for the close specification of odors. Briefly, the system recognizes but four constituents of any odor, namely: Fragrant (sweetness of flowers, etc.), Acid (sourness as of vinegar, camphor, etc.), Burnt (tarry), and Caprylic (goaty—somewhat like putrid).

By comparison with carefully chosen standards, the relative intensity on a scale of nine of each of the four component odor types present may be closely approximated and the entire odor expressed as a four digit number. For instance, the odor of vanillin (active principle in vanilla extract) is determined as 6021, meaning that it is as fragrant as standard 6 of the fragrant series, as nearly free from acid as standard zero of the acid series, and as burnt and caprylic as standards 2 and 1, respectively, in the burnt and caprylic series. A few other similarly specified odors are acetic acid, 3803; citral (from lemon extract), 6645; and oil of cloves, 7642. It is stated that no odor has yet been found which cannot be adequately defined in this way.

Allison and Katz devised an ingenious apparatus called an odorometer in which a measured and uniform flow of air is secured by the use of venturi meters. The odor laden air is diluted with pure air until the limit of detection is reached.

In spite of all the attempts to effect scientific classification of kind and intensity of odor, however, we still rely upon adjectives to describe both quality and quantity. This method is used for determining odors in water according to standard methods of water analysis.

Summarizing these several methods of classification and measurement, we may describe odors somewhat as follows, recognizing fully the inadequacy of any subjective classification, and the inherent difficulties involved due to the fact that there is no standard nose, and that fatigue of the olfactory sense takes place very rapidly.

General Division of Odors:

Good and evil odors
Dissolved and diffused odors

Descriptive as to Kind:

aromatic	peaty	animal
fruity	acid	horsey
vegetable	grassy	garlic
spicy	earthy	onion
tarry	musty	fishy
sweetish	moldy	putrid
ammonia	honeysuckle	hydrogen sulphide

Descriptive as to Effect:

delectable	mephitic	prostrating
agreeable	nauseating	noxious
pleasant	repulsive	noisome
disagreeable	sickening	asphyxiating

Descriptive as to Character:

clinging	pungent	delicate
persistent	heavy	penetrating
elusive	light	

Descriptive as to Intensity:

detectable	noticeable	strong
very faint	distinct	very strong
faint	decided	extreme

Descriptive as to Habits:

peripatetic or wandering
intermittent
continuous

Thus, the state inspector when asked what odor he observed on his last visit to your sewage plant might reply: A good odor; peripatetic and delicate, faint and agreeably suggestive of honeysuckle, and not at all like the continuous, extremely strong, heavy, nauseating, often prostrating, putrid, evil odors of former days before the advent of the present-day operator with his modern methods of care and control.

Relation of Bad Odors to Health.—The belief that foul odors carry and transmit pestilence and disease had its inception long before Hippocrates lighted fires in the streets of Athens to purge the air of plague. This belief has persisted, for even today in many country districts typhoid fever is still regarded as emanating from foul sink drains.

Modern medical science cannot ascribe any known specific disease to odor and must conclude that the direct effect of odors upon health has not in any case been shown to be seriously injurious, except in the cases of certain toxic gases.

There are, however, indirect effects which cannot be passed by. Offensive odors and objectionable smells may cause discomfort, loss of appetite, headache, nausea and nervous disorders, depending upon the character of the smell and the susceptibility of the person affected. Then too, objectionable odors may have harmful effect upon persons who are ill from other causes.

The late Professor Whipple aptly remarked that: "If, however, the word health is extended to include the psychological as well as the physiological, if it includes human comfort as well as bodily functions, then odors do have an important influence on health. Odors have strong powers of suggestion and give pleasure, discomfort or disgust as the case may be. They may interfere with one's quiet and repose."

It matters not, therefore, whether discomfort and distress are caused by the psychological or physiological effects of odor. The illness is real and the alleged cause must be given due consideration. At this point it may be of interest to state, that in twenty years' experience around sewage plants the writer has never known an operator to be ill from causes or hazards ascribed to his work.

Factors Affecting Odor Intensity.—Odors from a common source vary greatly in travel range and intensity. They may be in one place today noticeably strong, and in another tomorrow, faint but still perceptible. Many factors contribute to these vagaries and apparent inconsistencies. The season of the year, particularly in changing climates, has a pronounced effect. Then too, the time of day has marked influence, since odors are distinctly more noticeable in early morning and after sundown than during the day. Evidently the sun rays possess a deodorizing power. It is well known also that moist air carries odors farther and with greater intensity than does dry air, and odors will travel farther in light airs and breezes than in strong winds where they are quickly dispersed. A low barometer and high humidity are almost essential to long distance odor travel, while wind direction and air currents largely determine what areas will be affected. Sometimes odors will descend to valleys and again rise to the highlands, with little of definiteness to account for their erratic wanderings.

Perhaps the greatest factor in differentiating between changing odor

intensities is the individual judgment of the observer, whose conclusions unfortunately are not always based upon unbiased investigation.

Results of Odors.—Objectionable odors are often cited as causing depreciation in property values. No one wishes to live or own property where noxious odors are prevalent or even occasional. Recognition of this aspect of the sewage disposal problem is the reason municipalities attempt to locate the treatment plants in isolated areas or else surround the sites with a substantial property border of several hundred feet to prevent residential development from encroaching too closely.

Then, too, there is always the question of the effect upon health as discussed previously. Litigation because of odors usually centers around damages due to depreciation of property values, impairment of health and disturbances of comfort and repose.

Sources of Odor around Sewage Works.—The sewage plant operator recognizes two types of odor around his plant. The first is the so-called local odor which may be quite strong at close quarters, but which is rarely noticed a distance beyond say 100 feet. The other is the so-called carrying odor, reaching sometimes, to quote court testimony, distances of several miles, Odors both local and migratory are rarely of constant intensity or duration. These variations make the smells more noticeable and in no small measure account for bringing many treatment plants into disrepute.

The first source of odor at a sewage plant is the sewage itself. Fresh sewage has a peculiar odor recognizable to most operators, but difficult to describe. It is a smell combining that of dishwater, soap suds, gasoline, body wastes, flavored with occasional characteristic smells from industry. This odor usually is not intense, oftentimes barely noticeable, but it is noticed at the entrance to the plant and, in consequence, is likely to create an unfavorable impression upon the lay visitor.

When sewage becomes old by reason of long travel, it first becomes stale, then septic, and the original odor gives way to the characteristic odor of hydrogen sulphide. The churning of sewage at inlet channels and tank outlets has a tendency to release the dissolved gases and intensify the odor.

Screenings as removed contain readily putrefactive substances as well as decomposed organic matter mostly in the form of feces. As long as the material remains wet there is little likelihood of odor. When, however, the mass dries, or is permitted to remain exposed for any length of time, objectionable odor will appear, the intensity depending upon the temperature and place of storage. When screenings are burned there is also the possibility of odors from the stack gases.

Oil and grease give rise to odors of various kinds and degrees. These wastes occur as crude oil from garages and refining plants, and as greases, fats and soaps from both household and industry. When these substances float on the surface or stick to the walls of channels or tanks they melt in

the sun, turn rancid and give off peculiarly nauseating and penetrating odors. Where oil and grease are removed in special devices, the recovered mixture of materials quickly becomes putrid unless promptly and properly disposed of.

Grit theoretically should have no odor. Most material, however, as removed from grit chambers has an odor that is peculiar to itself and can be described only as a grit chamber odor, unless the sour mash odor of recent times predominates. The reasons for this odor may be: Either excessive amounts of unstable organic matter due to abnormal conditions of the sewage, or to improper operation; or else, too long a period between cleanings; or, a combination of the two.

Where tanks have to be emptied for one reason or another, odors are likely to occur from exposed material on the bottom and adhering to the walls. The nozzles of trickling filters are veritable atomizers and the resulting odor is dependent upon the character and condition of the applied sewage. Profuse surface growths also often give off a rather pronounced odor.

Fresh sludge from primary settling tanks and from the activated-sludge process is highly putrescible and if exposed to the atmosphere either in empty tanks, on sludge beds or in lagoons is most likely to send out far-reaching odors, especially in warm weather. A well-digested sludge will produce very little odor and that of a non-carrying type.

The gases incident to sludge digestion have varying degrees of odor, but in general they must be regarded as potentially objectionable.

Filth and litter, if allowed to accumulate around the grounds and building, and untidiness in general add not a little to the bad odor propensities of a sewage works and must receive due recognition.

Control of Odor from Sewage Plants.—No branch of sanitary engineering has made more marked advance in the past ten years than is found in the improved methods of sewage plant operation. Outstanding in this field is the progress made in odor elimination and control. Current technical literature contains numerous articles describing troubles and cures.

In odor control the old adage still holds: An ounce of prevention is worth a pound of cure. Or using another illustration, it is better to put a rail around the cliff than to provide an ambulance in the valley. An odor anticipated and prevented is far preferable to an odor dissipated and complained of.

An oft repeated remark that people smell through their eyes is particularly applicable to sewage treatment plants. One thinks not of the minute amount of emanation in his nostrils, but of the material source from which that emanation has come. For this reason, one of the most effective means of odor prevention is orderliness and cleanliness about the various treatment devices. A well parked grounds with a few flowers and shrubs is an effective psychological deodorant. It is not without the realm of possibility to

substitute fragrance for stench. Employment of capable men for the prompt removal of grease and oil, screenings and grit at the point of production, and a liberal use of water and scrubbing brooms will greatly reduce the possibility of odors from these materials. At a recent sewage conference it was aptly and truthfully stated that a sewage plant smells the best that looks the best.

Covering of the treatment devices with suitable buildings is effective in confining temporary or intermittent odors and permitting their ultimate diffusion into the atmosphere. In this connection we are familiar with a 3,000,000 gallon housed Imhoff tank installation near a park and within 300 feet of residences which has been operating now for over five years without a single complaint from odor. It might be well to raise the question at this point relative to the advantages and disadvantages of advertising the sewage plant, however well it looks. Is it not better to let the plant sell itself to the public and let the laymen handle the advertising?

For destroying odors from gases there are records of several installations where the gas has been trapped and burned, with marked odor reduction, notably at Decatur, Ill., Rock Hill, S. C., and Austin, Texas.

For combating the odor of stale or septic sewage, and for arresting decomposition and thus preventing undesirable smells, suitable applications of chlorine gas with or without lime, according to circumstances, are both practicable and effective. This method of odor control has been recognized and used in various forms for many years. Bleaching powder or chloride of lime was used in 1911 for odor control ahead of sprinkling filters at Stratford-on-Avon, England, and in 1914 at this same plant all of the bleaching powder was applied to the crude sewage ahead of the settling tanks, such practice having proved to be an effective means of eliminating odors.

However, it is only within the past six years and largely through the efforts of Mr. Enslow, of the Chlorine Institute, by his encouragement and assistance to plant operators, that the possibilities of chlorine around a sewage works have been better recognized and developed. Used primarily as a temporary expedient to bridle and check rampant odors, chlorine has won a permanent place as an effective aid in the treatment processes. The use of chlorine has been attended with such success as to warrant, in the design of all works, a provision for chlorination both as an aid to treatment and as a safety device against sources of complaint.

The use of chlorine in sewers ahead of the treatment devices, in conjunction with and as an adjunct to a program of rigid orderliness and cleanliness in routine operation, will go far toward removing the odor stigma from and establishing a good reputation for the much maligned sewage works. The first year's operation of a plant usually establishes its reputation. It is extremely important, therefore, that every effort be made to keep the plant clean, orderly and without offensive odor from the start.

What Constitutes an Offensive Odor.—It is a matter of common consent that disagreeable smells are not to be endured. We are all in accord with Montaigne who says, "I am nevertheless a great lover of pleasant smells and as much abominate the ill ones." What then constitutes an offensive odor or one which creates a nuisance? It was in 1875 that Disraeli's famous act defining a bad smell as a "nuisance" became law. The present conception of nuisance, "is anything that works an injury, harm or prejudice to an individual or the public." As far as the law is concerned, an odor nuisance, if action is taken by the government under police power, must be proved to affect "public health, safety, morals or the like." The modern tendency is to extend the police power to cover public welfare and to let the phrase "and the like," cover public comfort, quiet and repose.

According to one authority a nuisance is whatever the court decides is a nuisance. Attempts to provide a comprehensive definition are fruitless since the answer in particular instances is the composite opinion of twelve peers, formerly "all good men and true," but now partly women. Further, it is likely that twelve jurors in New York would not have the same opinion as twelve from Missouri on the same evidence.

Our attitude concerning smell depends upon our hereditary make-up, our environment and associations. The African native has a disagreeable odor in the nostrils of a European, and the European, we are told, is still more offensive to the olfactory sense of a Mongolian. In early days a man in America could use perfume and powder and still be a man among men. If he used the same scents today he would be ostracized.

Odors are sometimes tolerated by reason of expediency or necessity. The smells of a tannery in a small town may make meal time a total loss to the hotel's transient guest, but to the natives the tannery means a livelihood and for this reason its smells are countenanced. For a similar reason the far reaching and penetrating odors from the fish-drying communities on the coasts of New England and Nova Scotia receive slight comment from the residents. But the stranger, unfamiliar with the process, is driven from the environment.

Then too, certain odors are tolerated in one place, but are distinctly taboo in another. For example, the odor of a cowstable may not be unpleasant while working in the barn, but is decidedly objectionable in the dining room at meal time. Even the delectable geranium odor is most disagreeable when caused by organisms in a glass of drinking water. The same applies to other odors which might be appropriate and acceptable elsewhere.

During an extended investigation of odor nuisance from oil refineries around Providence, Rhode Island, a few years ago by the State Department of Health, an attempt was made to express quantitatively the degree or

magnitude of the nuisance caused by odors arising from any specific source. Various assumptions were reduced to a formula, including factors for the total days of the observation period, the number of days odor was noticed, the total hours of odor, the population affected and the average intensity of the odor. From reports of observations, notwithstanding that some of the data were necessarily variable and unreliable, a numerical comparison of the relative degree of nuisance from eight different sources was deduced.

It is extremely difficult, however, to determine definitely just what kind of odor, and just how much there must be to constitute a nuisance. Differences in the actual olfactory senses and honest opinions of people are further confused by psychological prejudices coupled oftentimes with ulterior motives.

It may be safely stated, however, that odors from a sewage plant which occur frequently and of sufficient intensity and offensiveness so as to cause continuous comment or complaint from a majority of those exposed to them, must be regarded as a nuisance, and as such be eliminated.

It is important, therefore, in every sewage plant as a part of the operation routine, that a record be kept of the occurrence and intensity of odors, if any, emanating from the works to a distance of say 1000 feet. In this connection, also, it may be found that smells attributed to the sewage plant have their source elsewhere, which fact should be made a matter of record. For this work it is important to secure unbiased observers, and those whose reactions to certain odors are similar. The value of such data may at times more than repay the cost of obtaining them and may go far toward establishing whether conditions complained of actually constituted a nuisance.

Can a Sewage Plant Be Operated without Offensive Odor.—An ancient proverb admonishes: "Look not for musk in a dog kennel." Is it logical, therefore, to expect that the dumping ground for the filth from an entire community will be entirely without offense to the senses of sight and smell? Some years ago during a conference with reference to odors from the Bath Sewage Disposal Works at Saltford it was recognized "that sewage disposal works could not be rendered entirely inodorous, and it was felt on many occasions the complainants had not sufficiently appreciated that fact, and had exhibited an extreme degree of sensitiveness."

It is obvious that the overloaded plant of obsolete design cannot be expected to behave as well as a modern plant, yet we have in recent times seen some of these old plants dressed up and enjoying a respectable reputation. The modern plant is usually designed to forestall disagreeable smells, yet, unless proper personnel and adequate funds are provided for the most effective operation, ill repute is but a matter of a relatively short time.

The attention given by such conferences as this to the matter of improving sewage plant operation, has within the last ten years brought this art

from the limbo of nothingness to a place in the sun, and we have no hesitancy in predicting that the properly operated sewage plant of today and of the future will be entirely free from odor.

"Attempt the end, and never stand to doubt;
Nothing's so hard, but search will find it out."

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Gas Collection and Sludge Heating*

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Necessity of Applying Artificial Heat.—The necessity of the application of artificial heat for successful sludge digestion is apparent from consideration of two known facts.

(1) The bacterial activities depended upon for digestion are very sluggish at temperatures below 70° F. and come practically to a standstill at 60° F.

(2) Ground temperatures are the governing factor in digestion temperatures, if heat is not applied, and these temperatures in the northern United States are in the neighborhood of 55° F. during eight months of the year, and do not reach 70° F. at any time.

It has been held by advocates of two-story tanks that the flowing sewage in the sedimentation compartment lends it heat to the digestion compartment. Our experience has been that the temperature of the incoming sewage falls to 48° in the winter and reaches 70° only in the later summer. There are, of course, special cases in which higher sewage temperature prevails but for domestic sewage traveling any distance to reach the disposal works, the above may be taken as fair average values.

It is evident, therefore, that digestion at natural temperatures must be very inefficient and slow and will require very large capacity in the form of digestion tanks.

As soon as investigation had made it evident that the available natural temperature and the optimum digestion temperature were on opposite sides of a dividing line and that the natural temperatures approached this line for only a very brief period of the year and could not cross it, it became evident that artificial heat is necessary for efficient digestion.

Our first experiment was to check the suspicion that ground temperature was the controlling factor in Imhoff tank digestion and then, by the use of coal as fuel, to determine the amount of fuel required to bring the temperature back to the digestion range; but always with the idea in mind that once favorable conditions for digestion had been established, we could use the digestion gases for fuel.

During the summer of 1925 we constructed an earth digestion tank 40 feet square and 10 feet deep by the cut and fill method, using excavated material to form an embankment to increase the effective size of the tank. Since the embankment was necessarily sloping, the top was practically 50 feet square in size. When the tank was nearly full of sludge, a cover of two-inch planks was floated on the surface of the latter and a downwardly projecting fin was fitted to the edges of the cover for the purpose of trapping

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any gases formed, and compelling them to travel to the gas dome at the center of the cover.

This floating plank cover had several purposes:

(1) To keep all floating material submerged,
(2) To allow for collection and burning of gas in a safe manner
(3) To act as insulation,
(4) To prevent odors (as a result of 1 & 2 above).

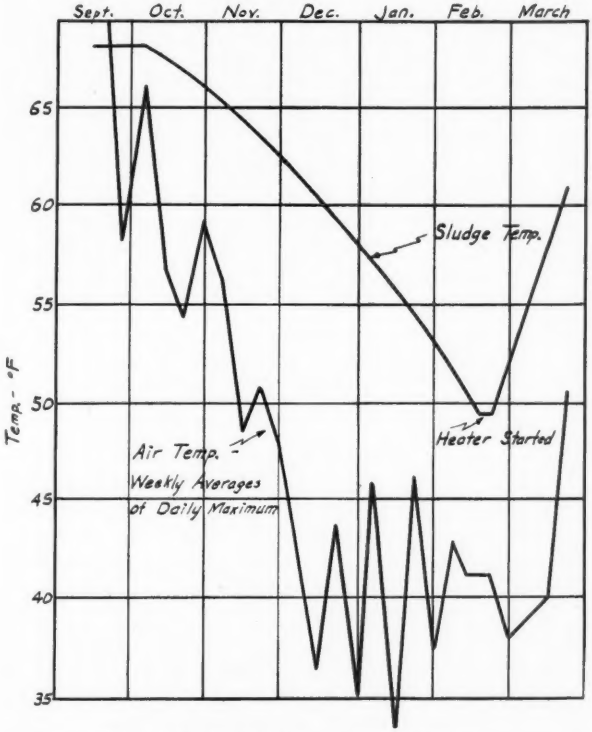

FIG. 1.—Sludge Heating. Downes 1925–26.

Size of Heating Grid Required.—A heating grid consisting of 140 feet of $1^1/_4$-in. black iron pipe was thrust under the cover along the line of slope of the top embankment until its lower edge rested on the tank bottom.

This heating grid was connected to both a gas boiler and a coal boiler in parallel, the circuit including a circulating pump.

From October, 1925, to February 22, 1926, the temperature of the sludge in this tank was allowed to take its natural course, with the result that for any given period the temperature of the sludge was the same as

that of the sludge in the Imhoff tanks. When the temperature had reached 48° F. and remained stationary at this point for one week, the coal burner was put into operation and the heating test begun.

Sludge Retains Heat.—In Figure 1, showing the result of this test, two important observations may be noted: first, the slowness with which the sludge gave up its heat in cooling, as evidenced by the divergence of the air and sludge temperature curves; second, the rapidity with which the temperature of the sludge rose when heat was applied to it. This is due to a peculiar characteristic of sludge by means of which it retains within its own bulk any heat applied and has little tendency to transfer such heat to the atmosphere or to adjacent liquid or other material. At a later time it was observed that with from 7 to 10 feet of sludge in the bottom of a digestion tank 20 feet deep, the sludge could be maintained at a temperature of 72° F. while the supernatant liquid above was at 60 degrees. The transition from the higher to the lower temperature took place within a 6-inch boundary zone at the sludge surface. The viscosity of the sludge inhibits convection currents and heat transfer must, therefore, be by conduction through the body of the sludge and by radiation from the boundaries of the sludge body.

With regard to the heat required we found that by burning an average of 150 pounds of coal per day we were able to raise the temperature of 1,500,000 pounds of sludge, one-half degree daily. This was at the rate of one pound of coal to 10,000 pounds of sludge; or one pound of coal raised 500 pounds of sludge, 1 degree.

Temperature and Circulating Time of Heating Water.—During the period of this experiment we studied the effect of different initial temperatures of the heating water and of different rates of circulation of the heating water. Neither of these variables is highly important within reasonable limits, since the heating process is regenerative.

The time of circulating the hot water through the system was varied from 7 to 15 minutes and the initial heating water temperature was varied from 90° to 122° F. Readings at regular intervals on the hot and returned water showed a drop of 16 degrees with the initial temperature 108; 28 degrees with the initial 120 and a circulating time of 8 minutes; 27 degrees with initial 120 and circulation in 9 minutes; and 30 degrees with initial 110 and circulation in 11 minutes.

Averages for three circulation periods indicated the following equivalent heat transfer:

Time	Degrees F. Drop	Degree-pounds in 24 Hours
8 min.	20	967,500
9 min.	27	1,161,000
11 min.	30	1,055,400

Since the average degree-pound of heat transferred was 1,061,300 or roughly 1,000,000; and 1,562,500 pounds of sludge was raised one-half degree per 24 hours during a month's run, equivalent to 781,250 degree-pounds per 24 hours, the loss of heat from the sludge was the differences between 1,061,300 and 781,250 or 280,050 degree-pounds, or B. t. u. per day or 26.3 per cent of the input.

In these tests the sludge was in direct contact with the ground and ground water at a temperature of 48° F. and presented a surface area of 2500 square feet to an atmosphere in the 30's and 40's. Of this area 2300 sq. ft. was protected from the atmosphere by a two-inch plank cover but because of the embankment slope at the top of the tank, 200 sq. ft was in direct contact with the atmosphere.

The information gained in these experiments showed that sludge heating was entirely practicable and also indicated that only a comparatively small heating coil would be required, since our grid with 53 square feet of surface was sufficient for raising the temperature of 25,000 cu. ft. of sludge one-half degree per day under winter conditions and under the unfavorable conditions as to exposure and contact with ground water related above.

In designing our concrete digestion tanks following this experience we found that with a tank of 40 feet diameter and 20 feet deep, one turn of two-inch pipe set 18 inches from the wall gave us about 110 ft. of coil having 61 sq. ft. of surface for 20,000 cu. ft. of sludge.

This has proved entirely adequate in practice over a period of more than four years. In fact, in this case we have not used a circulating pump but depend on the thermal difference for circulation. Under these conditions only a very small part of the coil was used since the hot water traveled slowly in the coil and gave up its heat long before the circuit was completed.

Incrustation of Heating Coils Not Serious.—Examination of the coils after three and one-half years service permitted us to answer the question so often raised with regard to incrustation on the heating coil. There was a crust about $^3/_8$ inch thick on the hot end of the coil, tapering off to zero about two-thirds of the distance around the coil. The logical conclusion is that the crust is formed at the higher temperatures and as such a crust becomes effective as an insulator at the inlet end of the coil the high temperatures are carried farther around the coil, allowing crust to be formed at more distant points. This is not very serious, however, unless we try to use too high temperatures. If the inlet temperatures are kept below 110° F. there would be little tendency to form crust; above 120° F. the tendency to incrustation is much more pronounced.

The conditions described above for our coils were brought about by the use of temperatures running anywhere from 100° to 140° F. but we estimated from the rate of progress of the crust along the coil that the latter would have a useful life of 9 years.

If, on the other hand, one used a high rate of circulation for the heating water and a high initial temperature so that the whole coil was at a temperature much above 120° F., the formation of a sludge crust on the outside of coil the would be quite rapid.

Design of Permanent Digesters.—In the design of our permanent concrete digestion tanks, based upon this preliminary investigation together with years of personal observation and experience, we were guided by the following considerations.

In order to minimize heat losses the bottom of the tank should be above normal ground water level and the concrete should be very dense so as to present a dry barrier against heat transmission to the earth. Against heat loss to the atmosphere, we provided a two-inch plank cover floated on the sludge. We had found in our preliminary investigations that a coating of white, lard-like grease from 1 to 3 inches thick formed on the under side of the planks, providing excellent insulation.

Keeping the entire tank above ground water level is comparatively simple as it is advantageous to pump green sludge to digestion tanks in order to mix and comminute it. The cost of such pumping is insignificant since the sludge produced from a million gallons of sewage amounts only to some 500 to 600 cubic feet. This represents, at most, one and one-half hours of pumping with a ball-valve 3-inch sludge pump which will run from six to eight hours on 1 gallon of gasoline.

Floor Slope with Lively Sludge.—The use of the conventional steep hopper bottom on the digestion tanks together with keeping the bottom entirely above normal ground-water level would, of course, carry a tank of any considerable capacity to an impracticable height. Instead of using such steep hoppers we used our heads, along the following line of thought.

The very steep hoppers in common use have been developed as the result of experience in handling three kinds of sludges: (1) pasty green sludge, (2) gritty sludge and (3) sludge which may have lain in the bottom of Imhoff or septic tanks for considerable periods of time and become inert and compact. At the bottom of a heated and controlled digestion tank we are interested in none of these types of sludge.

The sludge from such a digestion tank will be ripe and of an entirely different texture from that of green pasty sludge. It will be "lively" sludge, full of gas; such sludge as flows readily over the surface of a flat drying bed. Reasonable proportions of grit may be entrained in its mass and carried along. Where excessive quantities of grit are present in the raw sewage a grit chamber is an economy from every point of view. The sludge from such digestion tanks cannot possibly be of the same type as the old inert material that has lain all winter in the bottom of a septic tank. We have no space for such sludge. Our process is complete at the end of forty days and while it is in prime condition the sludge is drawn and dried.

How far dare we go in cutting down the hopper slopes? On the theory that a sludge which would spread readily on a flat drying bed did not require much slope in the tank floor, we built our tanks with a drop of eighteen inches in nineteen feet. That is approximately one vertical on twelve horizontal. Rather a bold stroke, or a case of "fools rush in," in the face of fixed tradition. However, it works. After three and one-half years of service, two of these tanks together yielded a total of two cubic yards of gritty material that had not gone out with the sludge. Most of this was trapped behind the concrete posts which support the heating pipe. No grit chambers were used during this period.

Hot Water Directly in Sludge Is Bad Practice.—In passing, may I say that the German practice of flushing hot water directly into the bottom of the sludge for heating is a bad practice as it tends to segregate not only the grit but coarse particles such as seeds, which would otherwise be entrained in and carried out by the sludge.

As to providing a dry barrier against heat loss in the form of dense concrete, this is accomplished by energetic rodding of all concrete to assure that there are no air bubbles left to make the concrete porous.

The floating cover provided as an insulation against loss of heat to the atmosphere, also provides the ideal means for the collection of the gas. In our preliminary investigation, we found that although the cover was originally laid flat on the sludge surface it assumed a slight camber in spite of the weight of the gas hood at its center. This natural camber, then was adopted as the shape of a cover subject to the least strain. This shape also provides for the complete submergence of all floating material without concentrating such material at the base of the gas dome, where it would become troublesome from two different angles, namely, in a tendency to crowd into the dome and clog it, and in presenting too thick a layer of scum for efficient digestion.

As a result of this natural camber the gas bubbles which can only rise vertically through the sludge are deflected along the underside of the cover toward the gas dome. In their lateral progress to the dome they produce a continuous gentle agitation of all surface material shaking out toxic by-products and causing solids to separate and fall. The efficacy of this action is apparent in the deposition of the white lard-like grease layer on the underside of the floating cover. The contrast of this pure white layer with the black material adjacent to it is most remarkable.

The bottom of our gas domes are wide open and 5 feet in diameter. Since the surface area of a 40 ft. tank is 1200 sq. ft. and the area of the base of a dome 5 ft. in diameter is only 19.5 sq. ft., the ebullition of the gas in this restricted area is so violent as to prevent clogging and to keep any scum broken up. The domes are three feet high. Inspection of three of the domes after four years of service showed that there had never been more

than eight inches of floating material in any of them and that splatter had reached a maximum height of two feet.

We feel perfectly free from explosion hazard since the weight of the cover maintains a constant positive pressure on the gas and, as the cover hugs the surface of the sludge during all operations, no air can ever get in. In fact we use no flame traps or other protective devices and only a drip pot, for the removal of excess moisture from the gas, intervenes between the gas dome and the burner.

The gas pressure may be maintained at any desired point by using the proper weight and freeboard. We get excellent results with unweighted wooden covers which give only $^3/_4$ inch gas pressure but unfortunately this low pressure precludes gas measurements with ordinary gas meters.

Quantity of Gas Produced.—Practically all workers in England and Germany agree with those in this country that in the experimental digestion of sludge, 1 gram of volatile matter digested yields 1000 cc. of gas.

It does not seem to be generally known that there is a definite relation between the percentage of volatile matter originally present in the green sludge and the proportion of such volatile which will be digested.

When sludge is ripe the volatile matter constitutes approximately 50 per cent of the total weight.

Figure 2 shows the general relation between percentage of volatile in the green sludge and the percentage of the total volatile matter which will be digested. This relation has been checked on a number of sludges from different parts of the country and the curve is here given in order that further data may be added.

As applied to Plainfield conditions, this rule would indicate the following theoretical gas yield:

One thousand persons yield 67.8 pounds or 30,750 gm. per day of solids in the settling tanks. Seventy-five per cent of the solids are volatile which is equal to 23,060 grams of volatile matter. Since we start with 75 pounds of volatile matter and 25 pounds of fixed solids in each hundred pounds of dry, green solids, and end with the same 25 pounds of fixed solids and 25 pounds of volatile matter in the ripe sludge (now 50% volatile,) there has been digested 50 pounds of volatile matter or 66.6% of that originally present. Then 66.6% $\times$ 23,060 grams gives 15,358 grams of volatile matter digested, yielding 15,358,000 cc. or 15,358 liters of gas = 542 cu. ft. per day. One thousand persons yield 542 cu. ft. of gas per day, and the gas yields 700 B. t. u. per cu. ft., so that we have available 379,400 B. t. u.

Heat Required.—One thousand persons yield 67.8 pounds dry solids, or 1356 pounds of 95% sludge (67.8 $\times$ 20).

To heat 1356 pounds of sludge from 48° to 80° F., that is, from normal winter sewage temperature to optimum digestion temperature, requires 1356 $\times$ (80-48) or 32 = 43,392 B. t. u.

It has just been shown that we have theoretically 379,400 B. t. u. available. My experience indicates that 80%, or 303,520 B. t. u., can be transferred to the sludge. A statement by Jones and Collier[1] on the operation of the Elyria, Ohio, plant would indicate that only 60% of the heat value of the gas was developed at the gas boiler. On this basis we have $379{,}400 \times 0.60 = 227{,}640$ B. t. u. of useful heat.

As reported earlier in this paper, my experience shows a radiation loss of approximately 26% from the digestion tank. This would indicate that 43,392 plus $43{,}392 \times 0.26 = 54{,}674$ B. t. u.'s are required and we have available, at 60% boiler efficiency as shown at Elyria, 227,640 B. t. u. per day.

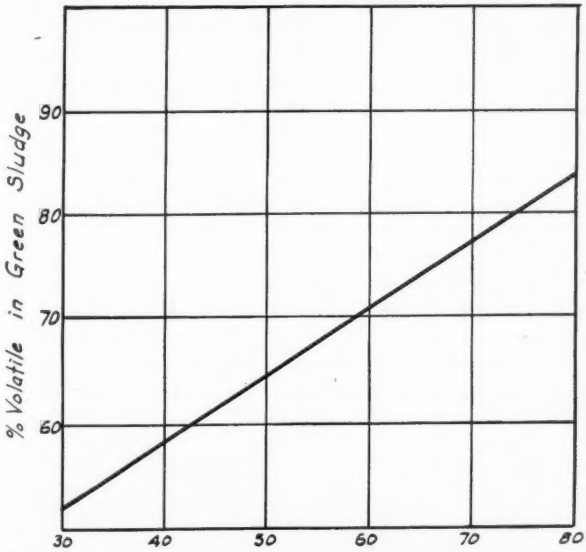

FIG. 2.—Per Cent Reduction in Volatile When Sludge Is Ripe. Downes 1931.

If we figure upon a digestion capacity of 1.25 cu. ft. per capita the sludge from 1000 persons would require 1250 cu. ft. A tank of convenient dimensions would be 12 ft. in diameter and 11 ft. deep. Such a tank of insulated steel buried in the ground would have a theoretical radiation loss during a 40-day digestion period of 3,117,380 B. t. u. for the sides and bottom and 1,387,008 for the top, on the basis of 32 degrees difference to the earth and 60 degrees difference to the air. This equals a loss of 112,610 B. t. u. per day. On this basis we require 43,392 plus 112,610 or 156,000 B. t. u. per day as against 227,640 B. t. u. available at 60% boiler efficiency.

Prüss states that under German conditions and a digestion temperature of 77° F. in a concrete tank of 50,000 cu. ft. capacity, well insulated, the average daily heat loss for the year is 22,500 B. t. u. per 1000 cu. ft. and that in winter with air temperatures below freezing the loss is 34,000 B. t. u. per day, per 1000 cu. ft. The addition of 3 per cent of fresh 95% sludge daily calls for the heating of 30 cu. ft. (1875 pounds) of sludge from the average yearly temperature of 54° to 77° F. or 48,000 B. t. u. For winter conditions (sewage at 50° F.) this figure reaches 56,000 B. t. u. The total heat requirement per 1000 cu. ft. amounts to an average of 70,000 B. t. u. for the year and 90,000 B. t. u. per day in the winter.

Since Prüss figures on winter sewage temperatures of 50° and winter air temperatures of 32° F. and my figures are for winter sewage temperatures of 48° F. and winter air temperatures of 20° F. the check is fairly close and indicates an abundance of gas for sludge heating purposes.

Thermophilic Digestion.—For thermophilic digestion (digestion at temperatures between 125° and 150° F.) although we require four times as much heat to raise the daily addition of green sludge from 50° to 150° F. as we do to raise the same quantity of sludge from 50° to 75° F., and, although the heat losses are four times as great per unit area and per unit of time, the time interval with digestion at 150° F. is cut to one-tenth that at 75° and the exposed surface area is cut to about one-fifth. The relation of areas bounding the sludge bodies for digestion at the two temperatures is not constant for all sizes of tanks but works out at one to five for digestion tanks to accommodate 20,000 persons at 150° and at 75° F.

The total volume of gas produced by complete digestion is the same in either case, but at the higher temperature is produced in one-tenth the time, so that we have ample gas in either case.

Heat required to raise sludge from 20,000 persons:

From 50° to 150° F.	3,750,000 B. t. u.
From 50° to 75° F.	937,500 B. t. u.

Heat losses from tanks to accommodate sludge from 20,000 persons:

At 150° F.; tank 15 ft. diameter × 12 ft. deep; 20,000 B. t. u. per hr.
At 75° F.; tank 40 ft. diameter × 20 ft. deep; 26,400 B. t. u. per hr.

Total heat required daily:

At 150° F.	4,230,000 B. t. u.
At 75° F.	1,571,000 B. t. u.

Total heat available daily (from Plainfield Sludge):

0.54 × 20,000 × 700	7,560,000 B. t. u.

Usable heat at 60% boiler efficiency, as at Elyria, O.:

0.60 × 7,560,000	4,536,000 B. t. u.

These figures are based on allowing four days for digestion at 150° F. or one-tenth the time necessary at 75° F. Indications, at present, are that

the process can be completed in 24 to 48 hours. However, the writer feels that in order to assure proper seeding and flexibility a capacity of four days should be allowed. If a greater period than four days is allowed, the area bounding the sludge body becomes so great as to permit excessive heat loss by radiation and to upset the heat balance.

For illustration, 150° F. has been chosen as representing the greatest heat demand and the greatest heat loss. Temperatures of 135° to 140° F. will probably prove adequate and may be maintained well within the heat balance provided by the flow of gas.

For purposes of comparison, heat losses at 75° and 150° F. have been computed on the basis of an insulated steel tank. Ordinarily tanks for the lower range would be made of concrete. The comparatively small size of tanks for digestion at the higher temperatures permits us to take advantage of maximum insulation at reasonable cost.

Power Plus Heat.—Mr. Weston Gavett points out that it is perfectly feasible to use the gas for power and still have sufficient heat for the sludge since the gas engine is very inefficient at best and gives up most of the thermal power of the gas as heat in the cooling water.

The gas engine is only 25% efficient; 15% of the power in the gas is used up as friction and 65% of the heat value is recoverable in the cooling water from the engine jacket and exhaust.

The 542 cubic feet of gas per thousand population per day computed for Plainfield, providing 379,400 B. t. u., may be developed into 1.1 hp. and still leave 65% of the heat value or 246, 610 B. t. u. for heating the sludge. If, as our experience indicates, 80% of this can be transferred to the sludge $246{,}610 \times 0.80 = 197{,}288$ B. t. u. is available as useful heat as against our winter requirement of 156,000 B. t. u. for heating the sludge and maintaining it at 80° F.

At Rockville Center, New York, Gavett, by digesting excess activated sludge with the preliminary sludge, secures from 1.5 to 2.0 hp. per 1000 population contributing and heats the sludge with the cooling water from the gas engines. Two engines are used, one direct connected to a 25 kw. generator and the other to a 700 cu. ft. per minute blower.

Cost of Gas Collection.—Gas collection is a convenience and is valuable as a means of minimizing odors. It is essential to the use of controlled digestion. However, we have been asked, "How much does the gas cost?" If we consider the cost of the cover and gas dome and piping to the edge of the tank as the capital investment and allow 12%, as suggested by Fulweiler for interest and depreciation, we find that the gas costs us from 15 to 33¢ per 1000 cu. ft. In one case, because the plant is running at low capacity, the cost is 44¢ but this will drop to 20¢ at full capacity.

Some investigators have claimed a large increase in gas production by stirring. However, most of the English and German authorities claim that

anything like constant stirring is detrimental to digestion. Prüss[2] claims that stirring doubles the volume of gas, while Sierp[3] states that the additional gas so liberated is only non-combustible CO_2 liberated from the saturated solution. The writer agrees with the latter, especially as many plants which do not use stirring are now getting all the gas that the organic content of the sludge digested can account for.

References

[1] *Proceedings N. J. Sewage Works Association*, 1931.
[2] Prüss, *Proceedings of the Association of Sewage Works Managers*, 1930.
[3] Sierp, SEWAGE WORKS JOURNAL (January, 1931).

Operation of Typical Sewage Disposal Plants in California*

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As a result of insistent desire for research work on sewage and waste disposal problems, a survey of existing plants was conducted by the State Department of Public Health during 1930 and 1931. A few typical plants were selected, at which detailed field and laboratory tests were made. Tests were made with little or no advance notice, so results may be considered typical.

Plants at St. Mary's College, Santa Barbara General Hospital and San Diego State Teachers' College were tested once for periods of two to three days. Those at Salinas, Lodi, Ojai, Pasadena, San Bernardino, Escondido and Pomona were tested twice for periods of three to five days.

It is interesting to note that in comparison with similar studies made by the United States Public Health Service in 1920 of fifteen representative plants in the United States, our California communities produce sewage two to three times as strong and the plants remove two to four times as much putrescible material per unit volume, showing higher percentage removals of suspended solids and oxygen demanding materials than do the eastern plants.

The average removals effected by settling tanks were 65 per cent of suspended matter, 44 per cent of biochemical oxygen demand and 19 per cent of total nitrogen.

The oxidizing devices, including final settling, showed average removals of 58 per cent of suspended matter, 88 per cent of B. O. D. and 70 per cent of total nitrogen. Over-all removals averaged 85 per cent of suspended matter, 93 per cent of B. O. D. and 76 per cent of total nitrogen.

A comparison of oxidizing devices showed that sand filters removed 88 per cent of suspended matter, 95 per cent of B. O. D. and 84 per cent of total nitrogen. Activated-sludge plants removed 88 per cent of suspended matter, 96 per cent of B. O. D. and 75 per cent of total nitrogen. Sprinkling filters removed 76 per cent of suspended matter, 86 per cent of B. O. D. and 66 per cent of total nitrogen.

These data are summarized in Table I.

TABLE I

RESULTS OF OPERATION OF SEWAGE TREATMENT WORKS IN CALIFORNIA

	Per Cent Removal					
	Settling Tanks	Oxidizing Devices	Over-All	Sprinkling Filters	Sand Filters	Activated Sludge
B. O. D.	44	88	93	86	95	96
Suspended Matter	65	58	85	76	88	88
Total Nitrogen	19	70	76	66	84	75

* *Presented before the Fourth Annual Meeting of the California Sewage Works Association, Monterey, Sept. 22, 1931.*

The studies brought out, in addition, a fact previously mentioned by others, that even with faulty design, negligent operation, overloading, presence of abnormal wastes and other unexpected contingencies, sewage disposal plants cause a marked improvement in the appearance, and a notable change in the constituents of the sewage.

It is a relatively simple matter to remove 30 to 50 per cent of the B. O. D. and suspended solids of a sewage by settling, but to remove consistently more than 50 per cent requires a combination of good design and careful

TABLE II

ANALYTICAL RESULTS, SURVEY OF SEWAGE TREATMENT WORKS IN CALIFORNIA

Results in Parts per Million

	Lodi	Salinas All	Salinas 1/2 Flow	Pasadena	Pomona	Escondido	Santa Barbara Gen'l Hosp.	San Bernardino	Ojai	St. Mary's Coll.	San Diego State Coll.
B. O. D.											
Raw.....	139	496	537	375	262	245	367	298	614	239	170
Final.....	10.7	31	8.3	14.3	4.9	6.8	4.5	26	5.4	24	7.6
% Removed...	92	94	98	96	98	97	99	91	99	90	96
Suspended Matter											
Raw.....	107	295	431	350	262	256	188	249	803	290	158
Final.....	16	21	25	42	44	32	50	36	22	22	56
% Removed...	85	93	94	88	83	88	73	85	97	92	65
Total Nitrogen											
Raw.....	29	50	48	48	45	37	25.5	37	76	44	49
Final.....	17	27.5	8	13	2.6	5	4	7	3.2	3	23
% Removed...	41	45	83	73	94	87	84	81	96	93	53
Oxides of Nitrogen in Effluent	1.3	1.4	17.8	5.5	7.5	4.5	4.8	6.3	11.8	12.1	3.1

operation. Similarly, sprinkling filters will easily remove 60 to 75 per cent of the B. O. D. of the applied sewage, and activated-sludge plants 90 to 95 per cent, but to get consistent residual B. O. D. in the effluent below 20 p. p. m. calls for an understanding by the operator of the intricacies of plant management, and watchful care at each step.

We must not lose sight of the fact that financial considerations frequently limit the efficiency of the plant, but each operator should make it his duty to get the most out of his plant for the time and money available.

Results of Survey

The results of these studies may be briefly summarized by plants as follows:

Lodi, with the first municipal activated-sludge plant in the state, treating during test periods a normal domestic sewage, showed a removal of 92 per cent of B. O. D. leaving 10.7 p. p. m., 85 per cent of suspended matter leaving 16 p. p. m. and 41 per cent of total nitrogen leaving 17 p. p. m. Oxides of nitrogen totaled 1.3 p. p. m.

Salinas, one of the latest activated-sludge plants in the state, treating a very strong sewage of unusual character, removed 94 per cent of B. O. D. leaving 31 p. p. m., 93 per cent of suspended matter leaving 21 p. p. m. and 45 per cent of total nitrogen leaving 27.5 p. p. m. Oxides of nitrogen totaled 1.4 p. p. m. With one-half flow, this plant removed 98, 94 and 83

per cent of suspended matter, B. O. D. and nitrogen, with residuals of 8.3, 25 and 8.0 p. p. m., and the effluent contained 17.8 p. p. m. oxides of nitrogen.

Pasadena, one of the early activated-sludge plants in the state, treating a strong domestic sewage, showed a removal of 97 per cent of B. O. D., leaving 14.3 p. p. m., 88 per cent of suspended matter leaving 42 p. p. m. and 74 per cent of total nitrogen leaving 13 p. p. m. Oxides of nitrogen totaled 5.5 p. p. m.

Pomona, having an activated-sludge plant preceded by an overloaded Imhoff tank, showed removals of 98 per cent of B. O. D., leaving 4.9 p. p. m., 85 per cent of suspended matter leaving 44 p. p. m. and 94 per cent of total nitrogen leaving 2.6 p. p. m. Oxides of nitrogen totaled 7.5 p. p. m.

Escondido, another later activated-sludge plant, treating average domestic sewage, removed 97 per cent of B. O. D., leaving 6.8 p. p. m., 88 per cent of suspended matter leaving 32 p. p. m. and 87 per cent of total nitrogen leaving 6.0 p. p. m. Oxides of nitrogen totaled 4.5 p. p. m.

Santa Barbara County General Hospital, an institutional plant of the activated-sludge type, employing a "Watsco" aerator, showed removal of 99 per cent of B. O. D. leaving 4.5 p. p. m., 73 per cent of suspended matter leaving 50 p. p. m. and 82 per cent of total nitrogen leaving 4.0 p. p. m. Oxides of nitrogen totaled 4.8 p. p. m.

San Bernardino, the largest Imhoff tank-sprinkling filter installation in the state, showed 91 per cent removal of B. O. D. leaving 26 p. p. m., 85 per cent of suspended matter leaving 36 p. p. m. and 81 per cent of total nitrogen leaving 7 p. p. m. Oxides of nitrogen totaled 6.3 p. p. m.

Ojai has a small plant with settling tanks, sprinkling filters and sand filters. The sprinkling-filter effluent, which included sludge liquor run directly to the filters, showed removals of 92 per cent of B. O. D. leaving 47 p. p. m., 90 per cent of suspended matter leaving 75 p. p. m. and 59 per cent of total nitrogen leaving 14.5 p. p. m. Oxides of nitrogen totaled 8.2 p. p. m. Including the sand filter the B. O. D. reduction was 99 per cent leaving 5.4 p. p. m., suspended matter 98 per cent, leaving 17 p. p. m. and total nitrogen 90 per cent leaving 3.2 p. p. m. Oxides of nitrogen were 11.0 p. p. m.

St. Mary's College has an institutional plant with Imhoff tank, sprinkling filter and sand filters. The dosing siphon was not functioning, sewage trickling through the sprinkling filter continuously during part of the test. In spite of this condition the removals shown were 70 per cent of B. O. D., leaving 73 p. p. m., 77 per cent of suspended matter leaving 66 p. p. m. and 32 per cent of total nitrogen leaving 30 p. p. m. Oxides of nitrogen were 4.9 p. p. m. The sand-filter effluent showed total removals of 90 per cent of B. O. D. leaving 24 p. p. m., 92 per cent of suspended matter leaving 22 p. p. m. and 93 per cent of total nitrogen leaving 3 p. p. m. Oxides of nitrogen were 12.1 p. p. m.

San Diego State Teachers' College has a new institutional plant with settling, sprinkling filters and sand beds. After a few days' operation, over-all removal was 96 per cent of B. O. D., 65 per cent of suspended solids and 53 per cent of total nitrogen. Residuals were 7.6 p. p. m. B. O. D., 56 p. p. m. suspended matter, 23 p. p. m. total nitrogen and oxides of nitrogen 3.1 p. p. m.

Comments on Operation

In addition to the measurable tests at each plant, notes were made of other items, particularly general cleanliness, weed control, beautification and interest of operator.

As might be expected, it was found that the plants producing the best results also rated high in the items noted. Another significant feature was the improvement noted between the first and second visits.

Sewage plant managers, superintendents and operators are in general interested in their work and anxious to get the best results possible. Good operation is easy to talk or write about, but often difficult to accomplish. What appear to be little things frequently make or break a plant from the operator's viewpoint. For example, let us consider some of the more common units of a sewage disposal plant:

Bar Screens, if of proper size and construction and well located, perform an extremely useful function at most plants, by protecting pumps and relieving succeeding units of rags, sticks and unsightly larger solids. If the task of cleaning and removing solids is clean, simple and convenient, much time and labor are saved. Self-cleaning mechanical screens are ideal, but where the cost does not seem justified, handcleaning at least twice a day is required. The screen should be located to give roominess and good air circulation, so that working around it will not be an odious task. It should be large enough to allow partial clogging between cleanings without unnecessary backing up of sewage in the outfall. Frequent difficulties observed are too wide openings, allowing all except large sticks to pass; too narrow openings requiring frequent cleaning or overflow where no provision for relief is made; combination with grit chambers with poor provision for removal of grit, or of such large capacity that they act as septic tanks; and no provision for draining and removal of material screened. A platform with perforations or bars, such as was recently built by Mr. Rossi at Modesto, takes overflow as well as serving to drain screenings. Basket screens with windlass for lifting, as at Escondido, Alturas and Sebastapol are good in deep sumps.

Too often an otherwise presentable plant has in one corner, over a bank or in an open pit, an unsightly, fly-breeding, odorous collection of screenings from the bar screens. Collection in tightly covered cans and disposal by

burial or burning is generally the approved plan for small plants, or they may be dried on a screen grid and burned as at Patton. Here a rag picker, resembling a series of meat hooks across the inlet to an Imhoff tank, takes out most simply a surprising lot of rags, ropes and papers.

Imhoff Tanks still lead in number as settling devices in this state. Few are provided with convenient means for dealing with scum in the flowing-through compartment or in the gas vent areas. The formula employed is to push or hose it down, only to have much of it bob up again, as well as to foul the effluent. San Bernardino and Los Gatos have scum overflows. Walks are usually located for structural economy rather than convenience to operator. Tanks built above ground with no railings are dangerous and liabilities to the city. The Davis Farm plant is a good example of protection. In many cases no water supply is available for cleaning or to allow the operator to wash after working around the tank. Screen houses over a tank, as at Patton, Norwalk Hospital and Montezuma School for Boys, are light, airy and keep scum soft. To my mind, these screened houses are superior to tighter housing. Where sludge capacity is limited or inadequate, sludge beds are also often found too small and the tank does not accomplish the purpose for which it was designed.

Clarifiers for raw sewage, with mechanical removal and separate digestion of sludge, are coming into favor in California as well as in other parts of the country and seem to confirm the contention that foaming and scum troubles are greatly reduced if not eliminated. Arrangement of inlet devices, scum removal and sludge removal facilities are often faulty, and the problem of handling overflow liquor is frequently troublesome. At Salinas scum difficulty is minimized by a flotation tank for skimmings with liquid returned to raw sewage. At the March, 1931, meeting of the New Jersey Sewage Works Association, Mr. Leroy Forman presented a paper giving results of studies at various separate sludge-digestion plants, from which the following concerning settling tanks "with or without mechanical scrapers" is quoted:

"In the operation of plain settling tanks too long a detention period is detrimental. * * * Solids should be removed either continuously at a low pumping rate or twice daily at a greater pumping rate. It is essential to keep the tank as free as possible from accumulated solids because fresh solids digest more quickly, and because of their nature are very putrescible and easily ferment, producing excessive foaming, scum odors, etc."

The use of a timed switch for sludge removal as at Santa Barbara County General Hospital plant seems desirable.

Separate Sludge Digestion with gas burning is now practiced at Chico, Salinas, Los Angeles County Sanitation District, San Bernardino, Escondido, Ojai and other plants and is helpful in odor control, cleanliness and operating efficiency.

Siphons in general receive little care. Regular cleaning and flushing, and checking up for air leaks to prevent continuous discharge, are important operating procedures. Stoppage by grease and air leaks are most common difficulties.

Sprinkling Filters require cleaning of nozzles, flushing or draining of distribution lines, and resting or treatment to prevent pooling. A galvanized-iron screen, of about No. 6 mesh wire, ahead of the dosing siphon will catch most of the larger particles such as matches, gum and balls of grease and thus save operating attention. Convenient means for flushing or draining, and valves for cutting out part of the bed for resting, are also desirable. Removal of nozzle spindles for one discharge is a convenient method of cleaning, but allowing them to remain longer only cuts down filter efficiency. Variation of clearness of effluent is due to unloading of slimes from rock surfaces and is to be expected in all filters.

Secondary Settling Tanks following filters should be provided with ample sludge capacity to take care of unloading periods, otherwise the final effluent at such times will be little better than that of the filter itself; furthermore the discharge is usually cyclic and the tank should be large enough to equalize the flow. Separate sludge digestion is satisfactory or return of sludge to the inlet of the primary settling tank, provided the rate of return is not too high. Plain settling tanks, Dortmund tanks, Imhoff tanks and mechanically operated clarifiers are all used in this state and if of proper size and kept free of excess sludge, all are satisfactory.

Activated-Sludge Plants probably present the most varied design and operation of any treatment methods. Ideas, experiments and experiences at different plants are so different that the designer would do well to allow ample size and the greatest possible flexibility in operation. Among the more common points frequently overlooked are: provision for carrying sludge return, use of a sufficient number of units to allow changes in number used for aeration and for reaeration; equalization of peak flows; arrangements for addition of sewage or return sludge at a number of points; continuous wasting of excess sludge; provision for cutting out one or more units for alteration, repairs or experimental use.

English practice tends toward mechanical aeration, while in this country the majority of plants built have used air under pressure. Recently a combination has come into favor, which is now being experimented with by Mr. Goudey at Los Angeles. Mechanical aeration does not produce as complete treatment or as "polished" an effluent as is obtained by use of air blowing, and this fact probably accounts for the reluctance of most American engineers to use it. An interesting point observed in literature on activated sludge is the conservative attitude adopted by engineers in plant design, which, however, is conservative as to cost of construction rather than in provision of flexibility and capacity for unusual sewage or

sewage flow. For example, A. J. Martin's "Activated Sludge Process" reports that experiments with reaeration of sludge have indicated for some sewages a marked advantage in using long periods and in diluting sludge with sewage, but many plants in this country provide no reaeration or only partial reaeration, consisting of blowing air through the sludge on its return from final clarifiers to the aeration tanks. Plants are all too frequently overloaded, and if of sufficient size, operation is usually made as economical, or perhaps better, as cheap as possible, with little or no attempt to modify operation for varying character and quantity of sewage flow.

Sand Filters, as used at St. Mary's College, Ojai and San Diego State Teachers' College, serve a useful purpose in continuously producing a sparkling, clear, stable effluent with a minimum of technical supervision. Sand filters are adapted to small plants where the relatively high construction cost, as compared with activated sludge, is balanced by the lower attendance and operating costs and the security afforded by a continuously good effluent. If operated flooded as slow sand filters they give remarkable bacterial efficiency but may cause algal growths and odors, necessitating a return to intermittent operation.

Sewage Ponds, or lagoons as they are termed in Germany, are used at Merced, Santa Rosa, Sonoma, Modesto, Calistoga and Sebastopol. They have furnished a cheap and effective method of overcoming odor nuisances where land is available and isolation reasonably good. They depend on algal growths for successful operation, the oxygen produced by the algae preventing septicization. Wind and sunlight, distribution and dilution with pond water are important factors. Care must be taken to control mosquitos. Area factors vary from 2 to 20 acres per 1000 people.

The Sacramento River at Sacramento this summer (1931) was in reality a large 500-acre sewage pond with little or no upland flow and distribution effected by wind and tide. Algal growths kept the water from becoming septic, dissolved oxygen tests showing from 25 to 200 per cent saturation. Population equivalent in terms of B. O. D. was somewhat over 200,000, giving an area factor of 2.5 acres per 1000 people.

Chlorination is an old story to many of you. It was surprising to find how many chlorinators were out of use for varying periods due to lack of repair parts, no chlorine on hand, and various minor difficulties, all of which resulted in no sterilization. Of seven plants with chlorination equipment visited during periods of tests, six had interruptions. It seemed obvious that where sterilization was needed there should have been duplication of chlorinators, scales, chlorine cylinders and chlorine rooms, and enough repair parts on hand to make simple repairs at the plant.

Sewage Treatment a Civic Responsibility

Generally, regardless of the methods of sewage treatment, we find the viewpoint of the city in the past has been somewhat as follows: A sewage disposal problem presented itself and, on the advice of the State Department of Public Health, an engineer was hired to make a report. After investigation a plant was designed, money voted and the project constructed. The cost of operation mentioned in the engineer's report seemed reasonable, but when bills actually are paid they seem excessive. The town has not grown as fast as estimates indicated and revenues are low. Demands for street work, lighting, parks, etc., came in, and the sewage work was left to the city engineer, superintendent of streets or plant operator with instructions to keep down costs. If no complaints of odor or nuisance came before the town board, the plant was allowed to drift, and requests of the operator for materials, supplies or repairs were put off as long as possible.

Gradually, municipalities are awakening to the fact that sewage disposal is an important civic responsibility. In a few places sewage effluent is sold for irrigation, in several sludge is sold for fertilizer, in many sewer farms are improved to a point where they become the showplace of the neighborhood rather than the shunned "sewer dump." As water shortage continues and becomes more acute, the value of sewage for irrigation becomes more appreciated as a certain continuous supply, and with appropriate treatment, depending on its proposed use, we can look forward to its more extensive utilization in California.

The success of sewage disposal after all depends on coöperation of municipal officials and the operating staff. If the operation is reliable, the plant clean and presentable, and the effluent uniformly good for the type of plant used, the officials will, as they should, take pride in bringing citizens and visitors to see how the sewage is handled.

The California Sewage Works Association is continuing its work of creating a new vision of sewage disposal and, by an interchange of ideas of those interested, bringing about better operation of sewage disposal plants in our state.

Camouflaging Sewage Treatment Plants*

BY P. N. DANIELS AND CHAS. H. CAPEN, JR.

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The dictionary definition of camouflage is "to disguise by masking." Camouflaging was used widely during the World War in connection with guns, ships and other articles of warfare. The sanitary engineer has a similar problem of disguise presented to him from time to time, for, to the average person, "sewage" means smell and "sewage plant" means an abiding place of foul odors. If, then, the engineer can make a sewage plant look like a florist's establishment with green houses attached, a comfort station, or even just a flag pole, the taxpayers in the vicinity will be comforted, their aesthetic sensibilities will not be antagonized, and no complaints of unbearable stenches will reach the local board of health.

This is particularly true of localities where the growth of population has been such that the original plant site, once quite a distance from a residential section, is now located in the center of the most recent suburban additions. The system of sewers, generally of the gravity type, concentrates at this one point and it is usually impossible, without extensive sewer relocation or pumping, to take the sewage to a more isolated site. In fact, as far as the metropolitan districts in New Jersey are concerned (around Philadelphia and New York), there are no isolated sites left in most of the small municipalities of the suburban type.

The same site problem occurs at the New Jersey ocean beaches in the northern section where all the sewer lines converge at the beach front, ending in most cases in a septic tank buried underground with an outfall pipe into the ocean from the effluent end of the tank. Practically all of these tanks were installed some 20 years ago, often under the supposition that all of the sewage solids would be "eaten up" by the bacteria and that the tanks would never require any further attention. As a matter of fact, the tanks never did get any attention and the municipal authorities, when confronted with the problem of replacing now outgrown installations, were quite indignant that the State Department of Health should require them to junk a plant which was supposedly good for all time. It then devolved upon the consulting engineers to find a site for a new modern plant or to design a plant with no open structures.

The authors, as consulting engineers for a number of municipalities in New Jersey, have had to solve these and allied problems in several of their designs and in the following "case histories" illustrate how they managed to camouflage plants under varying conditions of location and site.

Totowa.—The Totowa plant is one of the pioneers in the use of glass

* *Presented before the Fall Meeting of the New York State Sewage Works Association, Ithaca, N. Y., October 16, 1931.*

areas to enclose units other than sludge drying beds. As far as is known it was the first plant at which the modern large span type of glass cover was used over a sprinkling filter.

A high railroad bridge abuts the property on the left. The Passaic River runs in front of the plant and a county highway passes the rear, not fifty feet from the main building. Beyond the highway is a fine cemetery and beyond the bridge are a number of houses—the nearest being not more than 150 feet from the plant. These conditions precluded any design that would permit a nuisance, hence extreme precautions were taken.

A brick building houses a screen, grit chamber, two story or Imhoff tank

FIG. 1.—West Paterson Treatment Works. Brick Building Encloses Coarse Screen, Grit Chamber, Imhoff Tank and Chlorination Apparatus. Trickling Filter and Sludge Beds Glass-Covered.

and chlorination apparatus. In addition the unique feature of a blower is included. Suction lines lead from the sludge bed and sprinkling filter and the blower discharge is into a baffled chamber under the building roof to provide a period of contact with dry chlorine gas for deodorization. Discharge of treated gases is through the chimney.

A covered dosing tank adjoins the building and discharges into a glassed-over sprinkling filter 80 × 120 ft. in area. Final treatment is in a secondary settling basin. Glass-covered sludge beds are also provided.

Chlorine solution can be introduced into the screen chamber inlet, dosing tank inlet and final settling basin inlet. The latter receives a continuous dose and the basin serves also to afford a period of contact for the chlorine.

The plant was finished during cold weather. In order to permit completion without having to wait to prepare grassed slopes, it was decided to treat the slopes with white quartzite. This was the first instance of a sewage plant using this material for such a purpose. It has proven satisfactory where the slopes are not too steep or too long. Occasional raking is required to restore its uniformity.

The sludge bed is not provided with the customary tracks or overhead rail because it was considered necessary to back trucks up to the door and shovel sludge directly into them, as no disposal area is available at the site.

The plant is designed to serve 4000 persons and cost $110,000. It was built at the peak of high prices.

West Paterson.—This plant is almost across the river from the Totowa plant. Conditions and design are quite similar and the capacities are identical. (Figure 1.)

Paradoxically the plant is built on the hillside. A large part of the sewer system is on high ground and drains to the site by gravity. The low level area is drained to a pumping station which is just below the plant. The main reason for placing the plant so high was to keep the relatively valuable property along the county road available for other purposes. Inasmuch as pumping would be required regardless of location, it was found that the additional cost of lifting the sewage a few feet more was far outweighed by the greater value of the land near the main highway. The large number of trees on the site was taken into consideration and one of the units was moved slightly in order to save some trees.

Lower prices were available than for Totowa and the cost was about $95,000. Experience with the Totowa plant showed the value of plenty of daylight within the operating building. Window space in the building shown here is at a maximum. This aids greatly in operation.

The view in Figure 2 is given to show the method of treating the embankments with the white quartzite. The dark patch in the middle is a pile of leaves. This view was taken before the high embankment had been finally graded. Since the plant has been in operation it has been found that a high embankment of this type could have been better treated with rubble paving as the quartzite tends to slide on long slopes. The low embankments, however, lend themselves readily to this type of treatment.

The rough stone wall in the background breaks up the monotony of concrete construction and actually cost less than one of concrete.

Hawthorne.—Although it can hardly be said that the Hawthorne plant is camouflaged, it was designed with a view of permitting buildings much nearer than those now existing. Mechanical screens, sedimentation tank with scraping mechanisms, heated sludge-digestion tank, dosing tank, sprinkling filters, secondary sedimentation basins, chlorinators and glass-covered sludge beds are provided. The sprinkling filter was designed

so that, if and when required, a glass cover may be readily added. Concrete posts for supporting columns for roof trusses are set in positions corresponding to standard dimensions and the side walls are keyed to permit raising them to support a glass cover.

The plant cost $115,000 for the plant alone and a low-lift pumping station including chlorinators, gas burner, sludge lime feeder and sludge pump, cost $35,000. The capacity is 1,500,000 gallons per day.

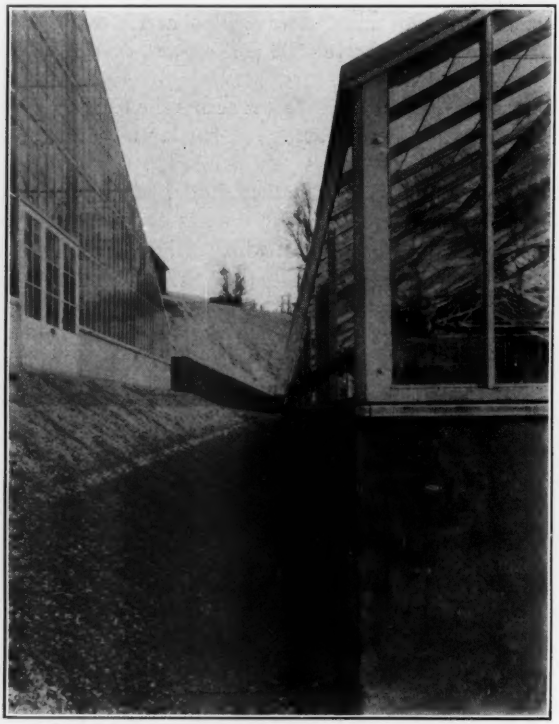

FIG. 2.—West Paterson Treatment Works. Foreground Shows Quartzite Embankment.

North Wildwood.—Along the New Jersey seacoast, disposal is to a large extent dependent on dilution. In the present case sedimentation, chlorination and sludge drying only are required. The settling basins are set with flow line just above ground level. A heavy reinforced concrete slab covers the tanks and serves to carry the sludge drying beds. Glass covers of the ridge-and-furrow type are used. Sludge is discharged by sludge pumps to the sludge domes shown in the center of the sand area. A very

fine pumping station is provided, the rear wall being shown in the background where it adjoins the sludge beds. (Figure 3.)

Haddon Heights.—Necessity is the mother of invention in sewage treatment as in other things. At this site an existing plant had to be revamped and the usual problem of nearby houses had to be considered. A certain amount of economy was required. The existing plant consisted of one-story settling basins, sand filters, chlorination and sludge beds. In order to utilize as much of the existing plant as possible, the settling basins

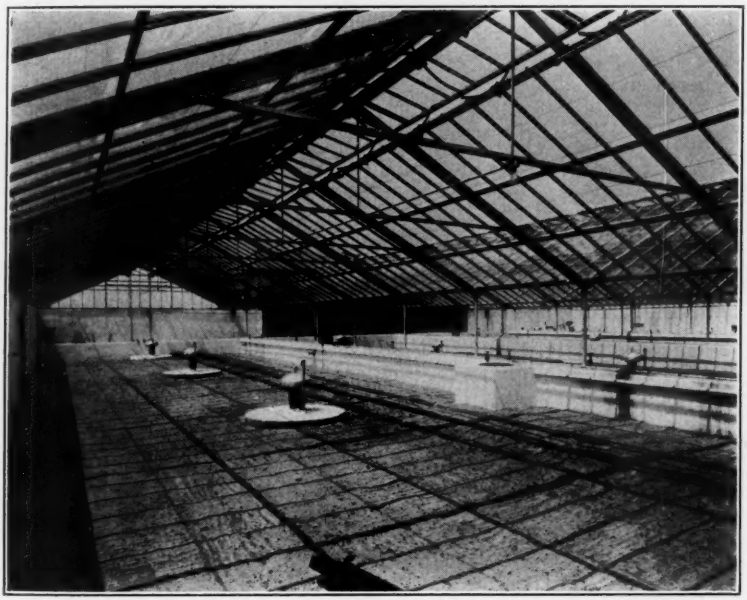

FIG. 3.—North Wildwood Treatment Works. Glass-Covered Sand Beds with Sludge Domes for Distribution of Sludge over Surface of Sand. Pumping Station in Background.

were converted into tight sludge-digestion tanks with gas collectors. The sprinkling filter was placed in a portion of the former sand filters and a glass cover was placed over this and an adjacent sand filter area, the latter being used as a sludge-drying bed. A vertical glass partition separates the filter and sludge bed.

The principal innovation at this plant was the use of a shallow bottom two-story settling basin, with provisions for frequent or daily removal of sludge. The excavation saved by this method more than paid for the cost of converting the existing tanks into separate sludge-digestion tanks.

In designing a glass-covered sprinkling filter, where the span is so great that intermediate posts are required to support the roof, great care must be taken in arranging the nozzles with respect to these posts. In some cases as many as ten designs were tentatively computed and laid out before selecting the final design.

Experience has shown that filter flies may be rendered far less troublesome under a glass enclosure. High summer temperatures often kill all the adult flies. Experiments have been made at this plant with cyanide gas and it has been found that not only adult flies but the larvae for a depth of about six inches may be effectively killed by this method. Great care must be exercised in the use of cyanide and so far it seems to have value only where the ultimate in fly control is necessary. Winter temperatures are not nearly as low as in an open filter and little or no trouble with ice is encountered. Spring unloading starts earlier and extends over a longer period.

The glass cover at Haddon Heights gave an excellent opportunity to study the effect of sewage gases on paint. Although a special paint without lead was used, blackening occurred to a certain extent in the filter cover but to lesser degree in the adjoining sludge bed cover.

Repainting over the filter is difficult due to the relatively high moisture content within the enclosure. Thoroughly dry surfaces can be obtained only by bypassing the filter prior to painting. Bolts seem particularly susceptible to discoloration and corrosion. Welded joints have an advantage for this reason.

Spring Lake.—The original Spring Lake sewage treatment plant was one of the septic tanks, mentioned heretofore, buried underneath the main boulevard at the ocean front. The tank as operated was full of sand, with a small passage forced through by the sewage flow, so that no removal of solids whatsoever occurred in the tank. The engineers not only had to enlarge and modernize this plant but also had to take in a plant of similar type located about a mile up the beach. The site available was the strip of park grass between the ocean boulevard and ocean boardwalk. It was adjacent to a very exclusive hotel, a casino bathing pavilion and several fine residences, so that there could be no evidence, either to sight or smell that there was a sewage treatment plant anywhere in the vicinity. This meant that practically the entire plant had to be underground, with the exception of a small pumping station superstructure architecturally designed to match the adjacent bathing pavilion.

The plant as designed and built consists of a mechanical bar screen; three 35 by 35 by 10 ft. Dorr clarifiers, a gas-heated Dorr digester and a pumping station. Ventilation was secured through a hollow steel flag pole 100 ft. high, with forced draft ventilation, for the clarifier and digester compartments plus the passageways between the units. Access to the tanks is through the pumping station. The capacity of the plant is 1,200,-

000 gallons per day, taking in the old plant and also the sewage from the plant up the beach through a trunk sewer. The cost was about $200,000.

Figure 4 shows the only portion of the plant visible above ground. The

FIG. 4.—Spring Lake Treatment Works. Superstructure of Pumping Station and Flag Pole for Discharge of Forced Draft Ventilation.

floor of this building houses pump motors, switchboard, recording meters, laboratory and chlorinators, all arranged with a view to compactness consistent with good design.

The black mushroom-topped stands in the background are air inlets to the clarifiers and digester, the ports below ground being provided with balanced dampers to prevent air from going out but permitting it to be drawn in from the outside.

The flag pole is of steel containing 0.2 per cent copper. Experience gained by the flag-pole manufacturers has shown that this copper content is

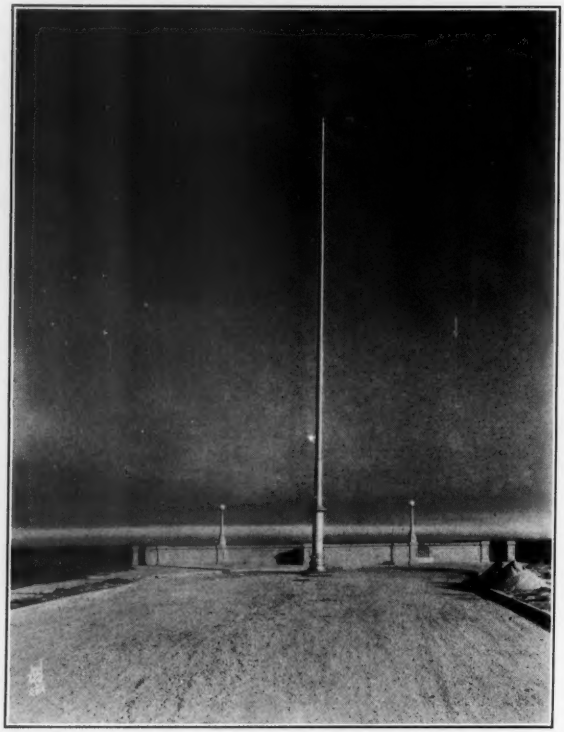

FIG. 5.—Deal Sewage Treatment Works. Pumping Station and Settling Tanks below Surface of Street. Forced Ventilation Discharges through Flag Pole.

satisfactory for use in salt air, and other sewage plants have used such poles with no visible deterioration from gases discharged. As far as is known this and the Deal plant (mentioned later) were the first instances of a forced draft discharge through a flag pole.

Long Branch.—The old Long Branch Sewer Company plant was located about $^1/_2$ block from the central business district of the town and

consisted merely of a series of wire screens. As these screens were normally raised 6 in. above the floor of the screen pit, it can be readily seen that there was not much of a screening problem for the operator. The screens were housed in an old brick building built in 1886.

Acting under orders from the State Department of Health, the Sewer Company proceeded to enlarge the plant so as to provide sedimentation and chlorination for a flow of 2,230,000 gallons per day. Here again the problem was to avoid the appearance of a sewage plant, not to mention the odor, and the task was particularly difficult, as the nearest residences were within 10 ft. of the edge of the building plot. Two 50 by 50 by 10 ft. 6 in.-Dorr clarifiers were designed to be housed in a mill-type superstructure, sludge being removed to a separate sludge-digestion tank built on the back of the lot. The old screen pit in the building was remodeled into wet and dry wells for the pumps, and the chlorinators were installed in a corner of the building. Sludge disposal, as in the case of Spring Lake, will be accomplished by pumping out to sea through thousand foot outfalls in the wintertime, this being permitted by the State Department of Health. The plant is not quite completed. The estimated cost is $125,000.

Deal.—Deal is a millionaire resort with million-dollar estates abutting on private beaches. Even the smallest lot would have been too expensive for a sewage treatment plant. It was, therefore, necessary to construct the entire 1,500,000 gallon-per-day plant under a street leading to the beach front. In this case, due to lack of room, the more modern methods of sedimentation could not be used and we were forced to fall back on a modern version of the conventional box-type septic tank, of which four were installed. The pumping station was put in behind a concrete sea wall at the beach front, elevating the grade of the street 4 ft. so as to furnish sufficient headroom. The only evidence of any underground structure, as seen from ground level, is a flight of stairs leading down beside the sea wall, giving access to the pumping station. (Figure 5.)

Due to the fact that power failure would have meant flooding of the motors and switchboard, it was necessary to put in a gasoline-driven generator standby unit to produce power for the pump motors in case of current interruption. This unit is entirely automatic and will start whether the operator is there or not. Ventilation is secured by forced draft through a hollow steel flag pole set in a traffic circle at the beach end of the street. The cost of the plant was about $200,000.

Conclusions

The above somewhat fragmentary descriptions of various installations designed by the writers are not intended to serve as examples of all the various camouflage devices which may be employed. They do indicate, we think, the majority of them. To date all of the plants described ap-

parently function properly without serious complaints, law suits or injunctions based on depreciation of property through proximity of the plant or injury to health and comfort from odors.

As is true of all sewage treatment plants, their successful functioning is dependent to a large extent upon efficient operation. We have been fortunate in securing good operators for most of the plants described. The good operators were obtained principally because of the State Department of Health licensing requirements, which demand that an operator pass an examination covering all the details and duties of his plant before he is permitted to operate it.

Suggestions for Increasing the Value of Sewage Treatment Works Data*

BY C. C. LARSON

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Questions that have arisen from time to time in the operation of the sewage treatment works at Springfield indicate that the analytical and operating data of a sewage treatment works might be better correlated or at least standardized so as to enhance their value from an engineering standpoint. The following discussion does not represent any particular original research on the part of the author, and no doubt many are already familiar with some of the ideas, but I believe they are of sufficient importance to warrant a certain amount of study even at the risk of repetition.

Average or Median?

At the end of each month most of us summarize our results merely by totaling our daily figures and dividing by the number of days, which gives us a daily average. The average or arithmetic mean is the simplest and most common method of generalizing the results of a set of observations and yet it has a number of shortcomings. It does not always give a true picture of the different items. Two groups may have the same average and yet be composed of very different items.

TABLE I

DISTRIBUTION OF VALUES WITH THE SAME AVERAGE

	6	1
	6	1
	7	2
	7	3
	9	28
Sum	35	35
Average	7	7

Each of the two columns in Table I shows an average of 7, and yet the individual values present an entirely different make-up. The abnormally large or freak item in the second column has unduly raised the average.

Figure 1 shows at a glance that the two groups in Table I are different from each other in spite of the fact that they have the same average.

If a group of values or items are arranged in the order of their numerical magnitude with the smallest at one end and the largest at the other they are said to be placed in "array."

* *Presented before the Forty-Sixth Annual Meeting of the Illinois Society of Engineers, Rockford, Illinois, Jan. 28, 1931.*

In an array the magnitude of the middle item is called the "median." In the above example the average for each group is 7, but the median for the first group is 7 and for the second group 2. The median may be the same as the mean, in fact it usually is near the mean, but in some cases it may be radically different. Its value lies in the fact that it is unaffected by abnormal items.

The "mode" is the magnitude of the item which is most common in a group. In one of our groups there are two sixes and two sevens indicating a mode of either of these values. In the other group the mode is clearly one.

Much of the foregoing discussion is taken from Whipple's book on "Vital Statistics," and is somewhat abstract. Just what application does it have to sewage treatment works data?

Table II is a tabulation of analyses of suspended solids for the month of

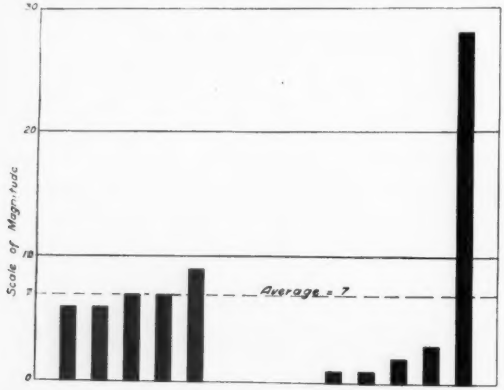


FIG. 1.—Distribution of Values with the Same Average.

September, 1929, from the treatment plant at Springfield. The first column shows the suspended solids in the raw sewage, which is the influent to the primary settling tanks, and the second column shows the solids in the effluent from these tanks. The figures at the bottom represent a strict arithmetic mean or average of their respective groups. Using these averages, the percentage of solids removed, or the efficiency of the primary treatment for that particular month, was 67 per cent, which is decidedly high. Let us analyze the separate items. In the first column there are three very high figures, namely, 832, 714 and 962. On these particular days heavy rainfall occurred and the flushing of streets and sewers contributed large amounts of suspended matter to the raw sewage. Is it entirely fair to include these abnormal values in the monthly summary? Are we not more concerned with the performance of the tanks on 27 days of the month rather than on these three exceptional days?

For the purpose of this discussion let us eliminate the figures for these days and recalculate the averages. Columns 3 and 4 are calculated in this manner. The per cent of solids removed or efficiency of the tanks on this basis is only 52 per cent, a quite different figure from the first and yet undoubtedly more representative of the tank performance during the greater part of the month. We are hardly justified, however, in completely ignoring the excellent behavior of the tanks on the three abnormal days. It is interesting to note that on these days the solids in the effluent from the tanks were practically the same as on other days. This may be accounted for by the fact that the type of suspended matter contributed by a flushing

TABLE II

PARTS PER MILLION OF SUSPENDED SOLIDS REMOVED BY PRIMARY SETTLING TANKS

Influent	Effluent	Influent	Effluent		Influent	Effluent
146	60	146	60		108	60
832	96	...	...		136	66
298	126	298	126		144	66
250	86	250	86		146	70
144	66	144	66		152	74
136	76	136	76		158	76
302	102	302	102		166	78
262	94	262	94		168	78
158	70	158	70		190	84
190	96	190	96		196	86
228	100	228	100		214	94
196	74	196	74		228	94
276	84	276	84		246	96
214	108	214	108		250	96
246	200	246	200		262	100
714	144	...	...		276	102
168	78	168	78		298	108
108	66	108	66		302	126
166	170	166	170		714	144
152	94	152	94		832	170
962	78	...	...		962	200
Average 293	98	202	97	Median	214	94
Per cent removal 67%		52%			56%	

rain is quite dense and settles out readily. Consequently the tanks show a very high efficiency on such days.

It has been noted previously that a median figure minimizes and robs abnormal items of their significance. Let us calculate the tank efficiency using the median figures instead of the averages. In columns 5 and 6 the figures are arranged in the form of an array. There is a total of twenty-one items, so number eleven will represent the median, which in the case of the raw sewage is 214 and for the primary effluent is 94. The efficiency calculated on these figures is 56 per cent. Is it not evident that this is a more representative figure than the 67 per cent and still we are not

guilty of ignoring the very commendable results achieved on the three days in question.

Most of us have, no doubt, blindly accepted the arithmetic average as the ideal method of summarizing a group of results without inquiring into its advantages or disadvantages. The above analysis serves to show, however, that oftentimes an average figure may lead to false conclusions. I have not inquired into the advantages of a "mode," but I doubt if it would be of any value where so many and such widely separated items are involved.

Rate of Gas Production

The production and collection of the gas resulting from the anaerobic digestion of sewage solids is at present occupying the attention of everyone interested in sewage treatment. In most cases the standard used in reporting gas production is the number of cubic feet of gas per capita. This, however, is a very indefinite standard and often leads to incorrect conclusions as to the efficiency of different types of digestion units. In the first place it makes no distinction between sewerage systems receiving only sanitary sewage and those which receive both sanitary sewage and storm water. Second, it gives no indication as to the presence or absence of industrial wastes nor to the gas producing ability of the same. Wastes from a starch plant or creamery produce enormous quantities of gas and yet the production rate is calculated on a basis of population only.

It is pretty generally understood that the gas is produced from the digestion of the organic matter in the sewage. A certain amount of this organic matter may be in solution but the bulk of it is present as solid material when it is placed in the digestion tank. Inasmuch as the mechanism of the reaction consists in the conversion of solid organic matter into volatile matter, it would seem to be reasonable to report gas production on the basis of volatile suspended solids, as determined in the laboratory, rather than on the per capita basis. A standard of this nature, which is already receiving some attention, is cubic feet of gas per pound of volatile solids added to a digestion unit.

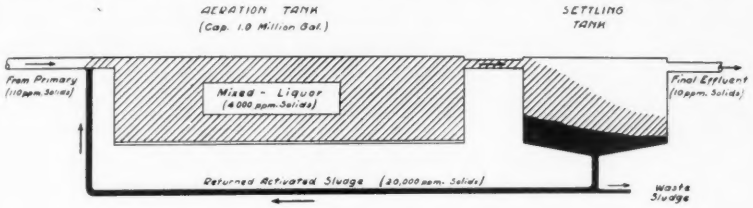
For the purpose of design it might still be convenient to convert back to a population basis, but certainly if the results from one plant are to be compared with those from another it is important that we agree upon a comparable standard and then convert all of our readings to that standard.

Standard Gas Volume

Just what do we mean when we refer to a cubic foot of gas or a cubic foot of air? The volume of a gas is so easily affected by changes in temperature and pressure that in order to obtain comparable figures we must correct our observed volumes to a common basis or standard condition. We were taught in elementary chemistry that the standard conditions of pressure

and temperature were 760 millimeters of mercury, or one atmosphere, and zero degrees Centigrade, and in most scientific work this standard prevails. The commercial gas industry has, however, developed a set of standard conditions all its own which is something different, namely, 30 inches of mercury and 60 degrees Fahrenheit. Thirty inches is the same as 760 millimeters, so that the pressure standard is identical, but the temperature is different.

Which of these standards are we going to use in presenting sewage treatment works data? In reporting gas production it would appear reasonable that we should adopt the standard of the gas trade, because all gas machinery is calibrated on a 30–60 basis. On the other hand, if we are referring to volumes of air in connection with the activated-sludge process the natural tendency is to use the scientific standard. Either standard would



Flow = 3.0 M.G.D. (x 8.3) = 25 million pounds daily

Wt. of Solids Accumulated Daily = 2500 pounds

Cap. of Aeration Tank = 1.0 mil. gal. (x 8.3) = 8.3 mil. pounds

Total Wt. of Solids in Mixed Liquor = 8.3 x 4000 = 33,200 lbs.

DISPLACEMENT PERIOD = $\frac{33200}{2500}$ = 13.5 Days

FIG. 2.—Schematic Diagram of Solids Accumulation in an Activated-Sludge Plant.

be satisfactory for our purpose but certainly if we are to avoid confusion it is important that we adopt one and discard the other.

Activated-Sludge Data

The next point which I would like to discuss might be referred to as a new yardstick for rating activated-sludge units. The idea and formula were proposed by Mr. R. H. Gould, Sanitary Engineer for the City of New York. Mr. Gould suggests that the operation and design of activated-sludge plants may be based on or at least may be related to the average length of time that the sludge is retained in the aeration tank. The calculation of this retention or displacement period, although not especially involved, is interesting and serves to bring out some features of the activated-sludge process which are not evident upon a superficial analysis.

Figure 2 is a schematic section of an activated-sludge unit showing the

aeration tank, final settling tank and the path of the returned sludge. For the purpose of this discussion we will assume that the capacity of the tank is one million gallons, the volume of flow through the unit is three million gallons per day, the solids content of the mixed liquor is 4000 p. p. m., the clarified sewage from the primary treatment contains 110 p. p. m., of suspended solids, and the final effluent contains 10 p. p. m. of solids. Removal of 100 p. p. m. from 3 m. g. d. amounts to 2500 lb. (dry weight) per day.

The aeration tank holds one million gallons of mixed liquor containing 4000 p. p. m. suspended solids, or 33,400 pounds. With solids accumulating at the rate of 2500 pounds per day it will require some 13.5 days in order to build up the 33,400 pounds necessary to fill the aeration tank. If we disregard short circuiting, this figure will represent the theoretical length of time which the sludge is retained in the tanks before it must be wasted. Mr. Gould refers to this figure as the displacement period of the activated-sludge unit.

It has been well established that at 20° C. all of the primary oxygen demand of sewage is satisfied under aerobic conditions in 20 days; about 90 per cent of this demand is satisfied in 10 days. If we assume that the oxygenation of activated sludge follows the same curve, our displacement period of 13.5 days should produce a sludge about 95 per cent stable. It has been demonstrated, however, by experiments of the Chicago Sanitary District and the U. S. Public Health Service that the rate of oxygenation is not the same for activated sludge as for sewage. This, of course, will affect the interpretation of the displacement period, but does not materially affect the calculation itself.

We usually assume that the function of an activated-sludge unit or in fact any secondary treatment is to deliver a liquid effluent of such a degree of purity that it will not injure the biological life of the stream into which it is discharged. In the light of the above discussion, however, it appears that the activated-sludge process performs a secondary function, that of stabilizing or satisfying the oxygen demand, in part at least, of the solid matter which it removes from the sewage.

Just what significance may be attached to this displacement period and whether or not it will be of any value from the standpoint of design remains to be seen. It does, however, represent a new angle of approach and is certainly of sufficient promise to warrant a certain amount of study.

Scope of Operating Records

It is my opinion that most of us err on the side of making too few tests and keeping insufficient records. In spite of the complete records which we endeavor to maintain at the Springfield plant we find occasionally

that we have not made sufficient determinations to supply the information requested by engineers and others visiting our plant.

Routine determinations sometimes become a burden and do not seem to justify the effort required. Very often, however, the real value of analytical work does not become evident until it has been summarized over long periods, and then it is possible to read into it meanings which one does not even suspect at the time of making the analyses. The same is true of keeping records. Events which at the time appear to be trivial and not worth recording oftentimes at a later date assume very important proportions.

By way of example let us refer back to Table II, column 1, the third item from the bottom. On that particular day the influent to the primary tanks contained 166 p. p. m. suspended solids, whereas the effluent showed 170 p. p. m. Upon looking up the date in the plant operating records, it developed that the primary tanks had been skimmed on that day. In the process of skimming, scum and floating solids were forced under the scum baffles, which accounted for the high solids content of the tank effluent. This serves to illustrate the importance of making note of all occasional or unusual operating conditions.

Most of us do not have the time nor facilities to carry on strictly experimental work, but after all, with the science of sewage treatment in its present stage of evolution the mere operation of a sewage treatment works is largely an experiment on a grand scale, and the relative size of the experiment should serve only to enhance the value of the results obtained.

Sewer Ventilation, Why and How?*

BY D. DONALDSON

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Do sewers require ventilation? They do, for at least three excellent reasons: (1) for the benefit of their contents, (2) for the security of their construction and (3) for the safety of the public and the sewer maintenance crews.

Somehow in the present-day complications of engineering, the simpler facts of common sense and past experience become pushed aside while we wander off into the scientific woods of argument and debate on less essential problems. It is, therefore, not to be wondered at that one monumental work on sewers, of some 750 pages, devotes 11 lines to ventilation of sewers. It may be that the subject is regarded as basically so obvious that every engineer should be self taught in its advantage, but when one studies the work done in the past few years in California and elsewhere it is apparent that ventilation of sewers is one of the last things thought of, if considered at all.

(1) **Why Will Ventilation Serve to Benefit the Sewer Contents?**—Oxygen is essential to aerobic action and its maintenance. If you close up a sewer system and allow only a limited quantity of air to filter in, under adverse conditions as regards its renewal, the oxygen supply is soon depleted and anaerobic action begins with all its objectionable consequences.

The superintendent of the disposal plant wants the sewage delivered to him in aerobic condition, and it is no excuse to say the distance is too great. In a fast flowing sewer many miles long, aerobic conditions can easily be maintained by ventilation; but if it is deliberately closed up so that fresh air is no longer available, the maintenance of aerobic conditions is practically impossible. Can that be considered good engineering? You say that you have complaints of smell and your nose confirms these. What do such conditions disclose to you? Is it the need for more ventilation or for less? If you know your business the answer is easy, and you will at once proceed to let the smells out by letting the air in. There is no other answer. Since 1850, when sewers were first installed for large projects, the question of their ventilation has been an active one. In 1857 Mr. Gurney, who had charge of heating and ventilation services of the British Houses of Parliament, where smells were too much in evidence from the adjacent Thames (at that time practically an open sewer), stated with regard to the closed sewers which carried the sewage that "As the noxious gases would be confined within the sewers themselves he recommended that special openings be made near the mouths of the sewers for burning the gases, they being inflammable when mixed in a certain ratio with at-

* *Presented before the Fourth Annual Meeting of the California Sewage Works Association, Monterey, Sept. 22, 1931.*

mospheric air." This indicates that from this early date ventilation was a recognized need and one of its possible forms was provided for.

In recent years you may have noticed another item of interest on ventilation, namely, that Dr. Imhoff has used the open ditch wherever possible for sewage conveyance. Why? For the better maintenance of oxygen content. His later ideas on purification of the Ruhr river by pooling, to obtain a greater surface contact, show common sense adaptation of nature's requirements for aerobic action.

(2) **Injury to Sewer Structures.**—Presuming the absence of ventilation because of ignorance of its essential need, or the deliberate creation of such conditions, the sewer contents are driven along a closed tunnel in which, in terms of its length, the conditions are more adverse with every mile. In such a sewer many things may happen to sewer materials which are no credit to the designer and in which no fault attaches to the failing materials.

In Southern California thousands of dollars have been spent in a futile attempt to box up sewage, with vain hopes that nothing will happen to the sewers. Since much did happen to them, instead of revised ideas on ventilation we find a continuance of the old notions plus more expensive constructions to withstand the objectionable consequences. In other words, we are fighting fresh air with dollars.

All over the world concrete and cement and sand has served and is serving excellently in sewers, even where the sewage is 5 times as concentrated as it ever will be in California. Why, therefore, does it fail here? Just for the reason so often referred to, lack of ventilation. Some of the older sewers in the City of London were, as are almost all main sewers there, built of brick, the inverts in cement mortar and the upper portions in lime mortar. Those sewers serve today and all their new main lines are of brick in cement mortar. They show no signs of the corrosive action complained of here, because their engineers long ago realized by experience the expensive consequences of inadequate ventilation. The function of good engineering is to start from the point of highest achievement and rise still higher, not to start away down in the scale making the same old blunders over again.

(3) **Safety for Sewer Maintenance Crews and the Public.**—In all sewer services, maintenance operations are at times necessary. For the safety of workmen engaged therein ventilation of sewers is the first and most important factor, and the engineer of design who fails in unremitting attention to the safety needs of this feature, should be called before the coroner to explain the carelessness for which he is criminally liable. When the ventilation conditions of the sewer are as carefully considered and provided for as are the hydraulic conditions, the engineer may feel he has done his duty, but not until then.

Modern conditions, with the automobile and its fluid and gaseous needs, have created new problems in sewer ventilation. Leakage from gas lines into sewer mains and not infrequently the gaseous products of industrial wastes also create new dangers. All of these have but one line of protection, which is not that of confinement but that of release through more and more ventilation. One part of illuminating gas to seven of air or a 1.5 per cent mixture of gasoline with air will create explosive mixtures.

Since life is the issue at question in this phase of sewer design no apology is offered for the addition to this paper, as an appendix, of the extremely excellent rules drawn up by Mr. Bell, A.M.I.C.E., Engineer to the Camberwell Boro Council, London, England. Every item of these rules and their provision should be adopted in toto by sewer maintenance engineers and carried out with the utmost care.

Entirely too many men have lost their lives in sewers in California, and conditions are still adverse. Until sewer ventilation and its needs are recognized, dangers will continue. Too much concern for the lives of their crews cannot be exercised by those in control of maintenance.

Danger to the public also arises in an unventilated sewer filled with explosive gases. Los Angeles has had some experiences along that line and other cities as well in damage to life and property and continuing danger.

Having said so much upon the matter of ventilation and "Why" sewers should be ventilated, what is to be said about the "How" of ventilation? Air replacement is a simple issue, in its elementary forms depending largely upon temperature relations and governed by conditions of inlet and outlet. In small pipe systems if effective inlet is provided by vented manhole covers, the sufficient outlet is made available by the house stacks. The American system, in which no disconnecting trap is placed upon the house lines, is much more favorable in this respect than is the European system, where house traps are invariably used. The European system, however, has a modern leaning toward the abolition of house traps for the purpose of securing the better ventilation incident to the American system. Having this good outlet why misuse it and prevent its being effective by refusing to supply the lower level inlet through open top manhole covers or other equally effective inlets.

In the larger lines, conditions requiring more extended consideration in design will occur. Owing to concentrations or other features of difficulty, each case must be taken up separately and from the conditions existing, a cure diagnosed whereby air will be automatically supplied, even by forced draft if necessary. In some cases low level inlets with stack high level outlets will serve. Where such conditions are not applicable, forced inlets or suction outlets must be supplied. In all cases the condition which all ventilation science aims at, namely, the required number of air changes per time unit, must be attained.

One simple criterion of a properly ventilated sewer system is the dryness of the walls of its structures. If the air changes are so frequent as to keep the sewer walls dry, the system is effectively ventilated, and in the absence of moisture the sulphide troubles also disappear.

The same engineer will design a tunnel and take endless pains to secure ventilation for the safety and security of the men working therein, but will pass up apparently without a thought the similar or more adverse conditions existing in a sewer (tunnel) in which workmen will necessarily be engaged, at any time or place. When our sewers get the same attention in ventilation that tunneling receives (tunneling regulation of New York State requires 100 cubic feet per minute per man), then the problem of sewer ventilation will have been largely solved and we will not be so likely to spend time and money in expensive chemical treatments as palliatives to a condition we ourselves have created. Stack pipes, no matter how high or how large, are useless unless there is an equal inlet service. This is a condition often forgotten; similarly, no amount of energy used in fan propulsion or suction will be effective lacking inlet service of equal capacity, at the lower point at which this can be supplied. Some very interesting material upon stack ventilation can be obtained from the Bureau of Standards investigations into minimum requirements for plumbing, under direction of the United States Department of Commerce. This can be secured for thirty-five cents from the Superintendent of Documents, Washington, D. C. See also Babbitt on "Plumbing."

It is no argument to introduce the matter of smells. One authority says, "If there are seriously objectionable odors from the manholes, such should be considered valuable as notices that the sewers are in a dangerous condition demanding immediate work to make them safe."

We have only touched the high spots of this subject in this sketchy paper. The science and history of sewer ventilation would fill many volumes, but we hope the matter submitted will receive the prompt attention it deserves not from the manner of its presentation, but from the essential seriousness as a factor in public security and economy; and in closing we may parody some well known lines:

"T'is AIR of which our sewers are scant
More AIR and fuller that they WANT."

APPENDIX

Regulation for Prevention of Accidents in Sewers Approved by the Camberwell Boro Council and Prepared by Mr. William Bell, A.M.I.C.E., Boro Engineer.

Published in *The Surveyor*, January 16, 1931

1. Each gang working in a sewer, which in these instances includes also any manhole, side entrance, sump or underground chambers, shall be pro-

vided with safety lamps (oil or electric), one detector lamp (Davis Boss or other approved type), one miners' safety lamp (where electric lamps only are used), lead acetate test papers in stoppered bottle, life line and safety sling in case.

2. Before men are allowed to enter any sewer as many openings as possible shall be uncovered and time allowed for the air to be changed.

3. When owing to the absence of ventilation, to unusual smells or to discharges from factories there is any doubt as to the purity of the air in any sewer, it shall be tested before any man enters the sewer by means of (*a*) detector lamp, (*b*) test papers, in the manner described in the printed instructions supplied with them.

4. These tests shall be also carried out or repeated, if any doubt arises as to the purity of the air while men are working in the sewer or have occasion to enter it.

5. No open light or fire shall be allowed near any entrance to a sewer. No smoking shall be permitted or naked lights used or matches struck in any sewer. No man working in any sewer shall, when in the sewer, have in his possession matches or any other means of creating a flame.

6. All oil lamps shall be lighted above ground at least 10 feet from sewer opening or further, if any smell of gas or other unusual smell is noticed. No damaged lamp (oil or electric) shall be taken into any sewer. If at any time this lamp (or any oil lamp where such is in use) is found to burn freely or a "cap" form over the flame, the men should at once withdraw and test the air as described in paragraph 3 above.

7. The only dangerous state of the air in sewers which the above tests might fail to detect is that due to the presence of poisonous gas. This is unlikely to occur.

Should, however, any unusual smell be met with in a sewer, especially a smell of almonds, the sewer shall be immediately vacated and a report made to the superintendent or foreman.

8. In all cases where safety chains or bars exist, such chains or bars shall be fixed across the sewers at the side entrance immediately below where the men are working by the man first entering the sewer. A lighted lamp shall be fixed above the chains or bars. In cases where no chains or bars exist, struts or other efficient substitutes shall be fixed at the same place with a lighted lamp above them.

9. No man shall enter any sewer unless there is a man stationed on top of manhole or entrance shaft at the place from which work is to be carried out. The man shall keep in touch with the men in the sewer by calling or signalling to them, if necessary, at frequent intervals.

10. In case of any accident to men working in sewers, and additional assistance being required, the London County Council Fire Brigade shall be at once connected with by telephone.

In answer to operator's query "Number, please?" the call is "Fire Brigade." When the Fire Brigade replies, the place and the fact that the accident is in a sewer should be stated.

For this purpose, foreman must ascertain location of the nearest phone (call box or private phone where available) before commencing work. When phone is not available the nearest fire alarm post should be used and arrival of the Fire Brigade awaited at the post.

11. The superintendent, foreman or man in charge shall take any further precautions he may consider necessary to meet special conditions in any particular case.

12. The superintendent or foreman shall obtain the signed statement of each man employed in the sewer department that he has been supplied with a copy of these rules and has read and understands them.

13. The superintendent or foreman shall be responsible for supplying each gang with the apparatus detailed in paragraph 1 above and for the satisfactory working conditions of the various articles.

14. The superintendent or foreman shall be responsible for all apparatus referred to in these regulations, being kept in good condition. Care must be taken to keep the life line and safety sling free from damp. They must be thoroughly examined at least once a month to ensure their good condition.

Explosions in Sewers and Sewer Maintenance*

BY W. T. KNOWLTON

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Ventilation.—Air in sewers should never be stagnant, but constantly in motion. This involves air escaping at some points and being renewed at others. If all impurities in the air above the sewage are thus oxidized, the air should not differ materially from that outside.

It has been thought by some that disease germs are carried in the air within the sewer. If the sewers are well built and well ventilated, there is very little, if any, danger that sewer gases will spread epidemics. In summer the air inside sewers, being cooler and heavier, will flow downward to the outlet. In winter the air is warmer than that outside and tends to rise. To prevent an upward current through the sewers from entering the house fixtures, the latter are trapped.

It has been the general practice for many years to carry the sewer gas directly through the house connection sewer to a point above the roof of the house. Some of the gas also finds an outlet through the holes in the manhole covers, on which account recent practice has eliminated all such holes, excepting a pick hole whereby the cover can be removed.

Where vents on bungalows are located along outfall and main sewers, as are found in Los Angeles, there has been complaint of odors from gases escaping from the roof vent when the air is heavy or damp. During foggy weather the odor of hydrogen sulphide coming from these sewers has at times been obnoxious to the neighborhood. To remedy these complaints the house connection sewers have been trapped at or near the property line.

Gas.—Although sewer gas may not be deadly to human life, the air may contain other gases that are dangerous. The presence of these gases lessens the vitality and renders the human system more liable to conquest by disease germs. Should, however, gas of an explosive nature find its way into the sewer, an extremely dangerous condition may be created, which can cause serious injury or loss of life if the gases should be ignited.

Leakage of illuminating gas into sewers happens occasionally and has frequently been the cause of explosions that have damaged property. Short circuits in electric wiring have at times given the spark necessary to ignite the gas. Where gas collects in sewer manholes, explosions have been caused by street cars passing over the manhole.

Gasoline.—The disposal of gasoline into the sewers is a matter of vital importance to all cities, and especially in those having many garages

* *Presented before the Fourth Annual Meeting of the California Sewage Works Association, Monterey, Sept. 22, 1931.*

and service stations. The discharge of gasoline into sewers can cause fires, as well as damage to the sewers, both of which are dangerous to the public welfare. In an explosion that occurred about two years ago in Los Angeles in an intercepting sewer on Slauson Avenue, between Avalon Boulevard and Western Avenue, thirty manhole covers were blown several feet into the air, some going as high as 25 feet, according to eye witnesses. Each of these covers weighed 220 pounds and several covers struck the pavement with such force that they were broken to pieces. At 9 A.M., when the explosion took place, Slauson Avenue was crowded with traffic, so it was miraculous that no persons were injured nor any automobiles damaged. The possible cause of this explosion was the ignition of gasoline vapors in the sewer manholes by a city asphalt heater working along the sewer line.

Combustible Gas Indicator.—As a result of the Slauson Avenue explosion, the Sewer Division of the Bureau of Engineering of the City of Los Angeles obtained the use of a gas indicator from the Los Angeles Gas and Electric Corporation and made a survey of the sewer manholes on Slauson Avenue and the sewerage system tributary thereto. This survey indicated that in many of these manholes there were considerable quantities of explosive gas. This gas was traced to oil refineries in the adjoining City of Vernon, which city discharges its sewage into the Los Angeles system. Steps to eliminate the discharge of gasoline into the sewers adjacent to the refineries were immediately taken by the Vernon officials. Subsequent tests along these sewers have shown that although there is some gas still in evidence in the manholes, it is in greatly reduced quantities and below the explosive point.

Since the explosion in Slauson Avenue, the Los Angeles Sewer Division purchased a Union Carbide Company combustible gas indicator which shows accurately the percentage of combustible gases up to 20 per cent above the lower explosive limit of such gases. The principle of operation of this indicator is based on the Wheatstone Bridge equation. The current is supplied from a mine-type storage battery through a meter box to a filament, all of which are in and a part of the indicator equipment. When this indicator is introduced into a combustible atmosphere, the combustible gas burning on the filament increases the heat of the filament and causes a change in the flow of the current through the meter, thereby moving the needle up the scale of combustible gas indication.

Survey of Gas Conditions in Sewer Manholes.—Believing that the use of this indicator would enable the City of Los Angeles to have some record of where and in what quantity combustible gas was contained in its sewerage system, a series of tests for such gas has been made in the manholes of all of the larger sewers of the city and to some extent in the smaller sewers. This survey work has covered an examination of about

1500 sewer manholes during the past eighteen months, and in many cases some of these manholes have been tested two or three times.

A study of the results of these tests indicated that the concentration of combustible gas varied, according to quantitative analyses throughout the city, and that it was above the danger point in 315 locations or 21 per cent of the manholes examined. As, however, there are about 50,000 manholes in the 2500 miles of sewers in the city system, one can have some idea of the magnitude of testing for this gas if all manholes in the system were to be examined. It is not considered, however, that such a complete examination is necessary, as many manholes can be omitted in sections where the survey indicates no gas to be present.

Illuminating Gas.—The leakage of illuminating gas into sewers and sewer manholes has frequently been found to be the cause of explosions. Not only in California, but throughout this country and abroad, there are records of explosions due to this cause. In Los Angeles this gas has found its way recently into a sewer under construction and, when ignited in some unknown manner, completely destroyed 350 feet of sewer, besides causing manhole covers to be blown 25 feet into the air. Fortunately no one was present when this explosion took place. In other parts of this city explosions have occurred from broken gas mains which injured workmen severely and in one case caused death. It is needless to say that the local gas companies in this city do everything in their power to prevent accidents. In fact these companies are coöperating with the city investigators in the work of tracing the source of gas entering the manholes.

As gas leakage may come from the breaking or cracking of a gas pipe, attention is called to the settlement in streets which takes place on account of excavations in private property. Unless there is close coöperation between those in charge of the supervision of buildings and those supervising street work, the settlement of the street may permit gas coming from such breaks to follow a filled ditch line and enter structures in the street or on private property. This settlement of street surface has occurred in Los Angeles and resulted in the breaking of utility pipes in the filled portion of the street. Arrangements are now pending to correct this condition by coöperation between the Bureau of Engineering and the Building Department of the city.

United States Bureau of Mines.—The United States Bureau of Mines has given considerable attention to the danger of combustible gases in manholes of public utilities. Six years ago this bureau conducted tests in telephone manholes in Pittsburgh and Philadelphia to determine the hazards from combustibles. The results of these tests were published in October, 1925, as a "Report of Investigations, No. 2710, of Gas Hazards in Street Manholes." A recent "Report of Investigations, No. 3109" was published by the United States Bureau of Mines in May, 1931, on "Gases

in Manholes," being a survey of the bureau in 1929 and 1930 of the gas conditions in the manholes of the Edison Electric Illuminating Company of Boston, Massachusetts. During this period of about a year, 1765 different manholes were tested, 107 of which showed the presence of combustible or sewer gas. The territory covered by the survey included 19 other cities in addition to the City of Boston. It may be noted, however, that the manholes in the outlying districts were usually free from gas.

Odors.—In conducting this survey in Boston, an odor or smell test was made of the atmosphere from each manhole, and it was noted that the smell test was positive in indicating large amounts of combustible gas, but did not give any indication of the relative amounts present. Where the majority of tests indicated a faint odor, combustibles were not present in amounts equal to 25 per cent of the lower explosive limit.

The Boston report states that it is a very dangerous procedure to rely on odors as an indication as to whether a manhole is safe to enter. A case is cited where there was no odor yet the air contained only 8.2 per cent of oxygen, which condition would have overcome a man entering such an atmosphere.

Carbon monoxide and hydrogen were present in all tests where combustibles were found to be equal in amount to 25 per cent of the lower explosive limit. It was therefore concluded that leakage of manufactured gas (of which carbon monoxide and hydrogen are normal constituents) was the chief source of combustibles in the manholes. This reasoning was substantiated by the fact that when repairs were made in gas mains in the vicinity of where carbon monoxide and hydrogen were found, explosive conditions in the manholes soon disappeared. In no case were gasoline or other hydrocarbons detected.

London Explosions.—In *The Surveyor and Municipal and County Engineer* for April 12, 1929, there is a condensed report of the commissioners appointed by the Home Secretary to inquire into the series of explosions and fires which occurred in London during December, 1928. This report states that the explosions were due to a mixture of coal gas and air, and that the gas was a gradual accumulation of leakage from neighboring gas mains extending over a considerable period and increased by some larger untraced escape within a short time of the explosion.

The commissioners recommended that all underground structures of any considerable size should be adequately and continuously ventilated, or if disused, filled in or removed. Coördination in control of underground services in London was urged.

Conclusions.—The recommendations in the London Report are applicable to conditions in many cities in the United States. Leakage from gas mains into underground conduits is a most frequent cause of explosions. The disposal of gasoline into sewers is not accidental like illuminating gas,

and arrangements should be made for the collection of waste oils and gasoline so their discharge into sewers may be prevented. Periodical examinations of air in sewer manholes should be included in sewer maintenance. Whenever and wherever the manhole tests indicate explosibility conditions, the coördination and coöperation of city authorities with the local gas companies should be required.

Sewer Maintenance in Philadelphia*

BY ALBERT H. MAINWARING

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Introduction

The City of Philadelphia covers an area of approximately 130 square miles and has within its boundaries over 2000 miles of sewers of various sizes and types of construction.

Maintenance Organization

The maintenance of these engineering structures, together with their appurtenances, is cared for by the Division of Bridges and Sewers of the Bureau of Highways, under the direction of the Chief of the Bureau, Dudley T. Corning.

The sewer maintenance branch of this organization comprises both an office and a field force, supervised by the Assistant Engineer in charge of the Division. The office personnel includes a stenographer and two clerks, and that of the field force two inspectors, a general foreman, six foremen, four sewer constructors (or bricklayers), six truck drivers and forty laborers. This field force is divided as follows:

(*a*) Five sewer district gangs
(*b*) A sewer cleaning gang
(*c*) A casting gang
(*d*) A storeyard gang
(*e*) An inspection crew

(*a*) A typical sewer district gang is made up of six laborers, a truck driver and a bricklayer, under the supervision of a foreman. They cover an area, or district, with boundaries worked out to keep the work of each gang unit as nearly balanced as possible. The duties of these gangs can be concisely stated as:

1. Repairs to the sewer structure itself,
2. The maintenance of the flow of sewage by the removal of stoppages and deposits,
3. The proper ventilation of the structure,
4. Physical inspections.

For this work each gang has a one and one-half ton truck of the covered body type, equipped with hip and body boots; oil skins; electric lanterns and the usual hand tools, including those used by bricklayers and carpenters; heavy duty and special short length sewer rods; standard fire hose,

* *Presented before the Fifth Annual Conference of the Pennsylvania Sewage Works Association, State College, June 24, 1931.*

with both an ordinary nozzle and a nozzle of the crawling type. Little "Ferret" nozzles, a turbine sewer cleaning machine, pressure bags of various sizes, together with both diaphragm and centrifugal pumps are available at the storeyard when needed.

(*b*) When the deposits in a sewer are so heavy that they cannot be removed by the use of flushing tools, the district gang is augmented by the addition of the sewer cleaning gang. This is made up of three laborers, equipped with a patented sewer cleaning machine. This machine is powered by an eight horsepower gasoline engine which drives a double drum hoist. The cables from this operate through an "A" frame placed over one manhole and through the necessary blocks, placed in another, dragging a bucket through the sewer. The machine lifts the bucket up out of the manhole and empties its load into a drop-bottom wagon which hauls it away to a dump. When manholes are in or adjacent to trolley tracks, this machine cannot be set up and it is then necessary to resort to the tedious job of hand cleaning.

(*c*) The casting gang is a separate unit of three laborers and a truck driver, supervised by a foreman. They are equipped with a truck and the necessary tools for the handling of inlet and manhole castings. It is their duty to cover the entire city and to replace all broken castings. The sewer district gang takes care of all castings in its district that have been merely knocked out of place. If the installation is a renewal of a manhole casting, the casting gang replaces the roadway paving in a safe but temporary manner, the permanent paving being cared for by the Bureau of Highways' district paving forces. If it is a new inlet casting, any repairs required to the footway paving are cared for permanently.

(*d*) The storeyard gang consists of three laborers. They help load the trucks; keep stock records of materials and act as yard watchmen. A supply of castings, inlet parts, terra cotta pipe, bricks, cement, concrete materials, etc., is maintained at the storeyard for the use of the gangs.

(*e*) The inspection force includes two laborers and two inspectors. The laborers patrol the Cobb's Creek intercepting sewer and see that the interceptor slots are kept free and clean so that they can function properly. This patrol is required by the State Board of Health to prevent pollution of the waters of the creek. The two inspectors are assigned to casting work. They work with the casting gang, outlining the day's duties for them, visiting and securing data relative to each location. With this information in hand they coöperate with the Department of Law in the handling of any claims that might arise against the city as a result of the breaking of the castings. These men also inspect the pouring of the metal at the foundry, since the Bureau of Highways secures all of its replacement castings by contract.

(*f*) The office force of three, as outlined above, cares for the usual time, job and cost records, pay roll sheets, special reports and correspondence.

Office Work

All job orders are issued to the foremen on a standard job order card, a duplicate being kept in the office. On the face, this card gives the location and description of the work, the date of issue, date of start and completion of the work and the foreman's name, district number and job number, together with the origin of the complaint. On the back of the card the foreman reports the nature of his repairs, all materials used and the job time record. From this and the daily time sheet the office compiles the cost record sheets. Separate sheets are tabulated and totaled for each gang and cover a period of one month. Individual job costs can readily be taken off this sheet. Monthly work reports are also tabulated. At the end of the year a summary of these becomes part of the annual report on the activities of the Division.

Gang Work

The summary sheet for the year 1929 is as follows:

MAINTENANCE OF SEWERS BY CITY FORCES—1929

Character of Work	No. of Jobs	Cost of Labor	Cost of Material	Teams and Trucks	Total
Choked inlets opened	1056	$11,577.60	$ 32.56	$ 290.36	$11,900.51
Repairs to inlets and manholes	2440	18,286.69	2,847.43	1,016.67	22,150.79
Sewer cleaning 37,616 ft.	365	12,675.12	79.50	1,526.58	14,281.20
Sewer breaks	206	10,144.60	937.62	279.89	11,362.11
Sewer examinations	685	5,238.16	0.90	143.66	5,382.72
Miscellaneous	249	6,457.38	2.28	200.62	6,660.28
Replaced castings	2414	5,164.46	18,334.24	879.02	24,377.72
New inlets built	21	1,309.54	877.85	183.30	2,370.69
Total	7436	$70,853.55	$23,112.37	$4,520.10	$98,485.02

Under the heading "Miscellaneous" is listed those complaints that upon investigation are found to be outside of the jurisdiction of this Division, as for instance, a complaint of water in the cellar, which has its source in a leaking water main or the privately owned house drain.

Analysis of the above report shows that the average day's work for a district gang was 3.4 jobs at an average total cost of $14.55 per job and a labor cost of $11.08. The casting gang averaged 8.4 jobs per day at a total cost of $10.09 a job with labor costs of $2.14. In figuring these totals neither the office overhead nor the cost of supervision by the Assistant Engineer has been included.

The summary sheet for 1929 has been used because this was the year that the Division changed from contract transportation to city-owned

trucks. In 1928 trucks were contracted for to care for the needs of the casting gang and of the two most northerly sewer districts; teams were used for the other three districts. By the substitution of city-owned trucks in 1929 an increase of 520 jobs was cared for, this being an increase of 7.8% for the Division. Although the casting gang had a truck in both years, the more readily controlled city-owned vehicle resulted in a 5.9 per cent increase, or the placing of 136 more castings in 1929 than in 1928. This increase was effected with a saving of over $2000 in transportation costs for the Division for this year.

Typical repair jobs of this same year are as follows:

Pearl Street, east of 13th Street, excavated and repaired 55 feet of a 4-foot circular sewer; labor costs, $551.01, materials $73.10, or a cost of $11.35 per foot.

Huntingdon and Emerald Streets, excavated and rebuilt 12 feet of a 3-foot circular sewer and repaired two drains; labor costs $42.88, material costs $35.00, or $6.50 a foot. This job was completed in ten hours.

Sewer Cleaning Gang

Typical jobs of the sewer cleaning gang are as follows:

1600 Block of North Bodine Street, cleaned 350 feet of a 3-foot sewer, cost $421.28.

Wildey Street—2nd to 3rd Streets, cleaned 363 feet of a 3-foot sewer, cost $1303.85.

Contract Work

In 1929 emergency contracts were also awarded and supervised by the Division, as follows:

Sansom Street, east of 44th Street, excavation and reconstruction of 52 feet of a 20-foot brick sewer, cost $30,766.91.

Dauphin Street, west of 16th Street, excavation and reconstruction of 40 feet of a 9 ft. 6 in.-circular brick sewer, cost $18,572.80.

Casting Work

Studies have been made of the design of the various castings used on manholes and both the open-mouth and drop-grate style of inlets. As a result, all open-mouth inlet castings are now made much heavier, and oblong inlet covers have been abandoned for round covers. Due to the added strength given the new style castings, together with a more rigid inspection of their pouring, the appropriation for castings has been reduced from $30,000 in 1926 to $17,000 in 1931.

The Division has also been able to maintain a stock of castings on hand and last year was able to purchase its own patterns. These patterns have

resulted in a lower cost per pound for metal and eliminate the slight variations that crept in when the successful low bidder was supplying his own patterns.

The change in open-mouth inlet covers from oblong to a patented round type has eliminated many damage suits against the City. The oblong covers often were improperly replaced in their seats, allowing them to tilt when stepped upon, resulting in accidents. This cannot happen with a round cover, nor can it drop down into the inlet. The Department of Law reports a decrease in suits instituted against the City from 2266 in 1927 to 389 in 1930 and credits the new style inlet cover as being a material help in this reduction.

Investigation of manhole covers has also been made. The present standard is a ribbed cast-iron cover with a flange depth of 3 inches. It supercedes an old standard cover of $1^1/_2$ inches in depth, which frequently broke under modern loadings and often was pushed out of its frame. The 3-inch cover has been found to stand up well. This is never knocked out and rarely breaks, replacements being due chiefly to the wearing down of the toe clips on heavy trucking streets.

In May of 1927, 12 rolled steel manhole covers were placed on heavy-duty streets under different types of traffic: pleasure car, bus and truck. These covers were 1 inch and $1^1/_2$ inches in thickness. They were placed in 3-inch standard flange frames, the difference in thickness being made up by a cast steel ring. To date we have had no complaints from any of these installations. They do not jump out or rattle. Recent examination shows that the seat of the cast iron frame has worn down $^1/_{16}$ inch and that this seat has worn into the cast steel ring $^3/_{32}$ inch; the ring into the underside of the plate for $^1/_{16}$ inch, and the top flange of the frame has worn down approximately $^1/_8$ inch. The treads rolled on the plate are beginning to wear smooth. Shop tests on these plates made with a 5500-pound steel ball, dropping from heights of 5 feet to 31 feet 6 inches produced no fracture at the maximum drop with an impact of 173,250 foot pounds. Plates were reversed on the manhole frame with each drop.

At the same time as the above tests, standard inlet castings of both the open-mouth and drop type were made up of cast steel and installed at locations that formerly required constant replacement of broken castings. To date these have not been broken, although they have been knocked out of place.

Patented pressed steel manhole frames and covers have been installed, one having been in service seven years and another five years.

Cast iron is still the standard owing to its lower cost, but the writer feels that a big improvement can be made in standard highway practice, particularly in regard to manhole castings, by the use of a combination of pressed steel frame and rolled steel cover, the frame to be designed in

such a manner as to allow of adjustment, or practical renewal without the necessity of tearing up the adjacent roadway paving.

Inlet Study

A study of inlet complaints in the central portion of the city over an area extending between the Delaware and the Schuylkill Rivers and from Spring Garden Street to South Street, inclusive, indicates that there are 2.3 more inlets of the drop type than of the open-mouth type.

Choked Inlets

In this area in 1929 there was a ratio of 2.65 choked inlets of the drop-grate type to one of the open-mouth type, so that from the standpoint of choking the two inlet types are practically equal, with the same number of installations. There was this advantage, however, for the drop grates: they were found to be choked in the inlet trap by an accumulation of fine silt, which is readily removable, while the open-mouth type was found to be choked in the neck of the inlet. This type of choking is not so easily remedied and frequently necessitates the breaking of the street paving and the excavation of the inlet neck. In nine cases out of ten it is found to be the open-mouth type inlet neck that has to be excavated.

Castings

From the standpoint of casting replacement in this same year, 20 open-mouth inlets required complete renewal to one of the drop grates whereas one and one-half drop grates to one open-mouth inlet required the replacement of broken lids or grates. In the matter of resets the ratio was 15 to 1 in favor of the drop grate type. The cost of a No. 2 open-mouth inlet casting complete, is $10.80 and of a No. 2 drop-grate inlet casting complete, $14.06. From this comparison it can be readily seen that from the standpoint of the maintenance engineer the drop-grate type of inlet has a decided advantage.

Conclusion

In closing I would like to bring attention to the splendid coöperation of the Division's personnel, particularly in those cases where a real element of danger exists.

They are regular in their attendance, and the percentage of sick leave is surprisingly low.

Salary turnover is also low. While the writer has not figured the percentages in either case, he considers it worthy of comment in face of the duties the men are sometimes called upon to perform.

Sewer Maintenance in a Small City*

BY ROY L. PHILLIPS

City Engineer, Meadville, Pennsylvania

It is not difficult to interest the community in a good looking water plant or a well-kept sewage treatment plant—or one that is not well kept, if the very obvious results of such an operation become apparent to the citizens living in the vicinity of the plant! But a sanitary sewer system lying entirely below ground, out of sight of the public, will also be out of the mind of the public. The better the system and the better the maintenance, the less attention or interest we will find on the part of the public. The only time such a system is brought to their attention is when the unusual happens.

Sewer systems in small communities vary greatly in all their details. Proper design and construction play such an important part in the maintenance problem that it might be well to mention here some of the factors. Many communities have adopted the combined system and taken the quickest and easiest method of disposing of both sanitary sewage and surface water by emptying such combined sewers, with good self-cleansing grades, into the nearest stream at a great number of different points along its banks. For these cities the maintenance problem has been rather simple. They do, however, face the construction of collection works, separation, etc., in order that they meet the requirements necessary before satisfactory treatment can be applied. Other cities took early advantage of good engineering advice and designed their sewers along lines which provided for the future handling of the sewage in a modern manner. These municipalities very often have been faced with difficult maintenance problems due to the flat grades which are often necessary in order that the sewage of an entire city may be collected at a given point and also due to the lack of natural flushing of these sewers by periodic storm flows.

Unquestionably it is a fact today that separate sewer systems are desirable for the small city, with at least primary treatment and, probably eventually, rather complete treatment in view. The combined system has some advantages, of course, but these are generally conceded to be exceeded by those of the separate system. The flow of the sanitary sewer system should be free from dilution and reduced to a minimum, particularly where pumping or complete treatment is involved. With this end in view, the best place to start maintenance is with the construction of the original system and all additions thereto. Every effort should be made to keep out surface water, grit and all matter not properly classified as sanitary sewage. Cleansing velocities should be provided where possible, joints

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should be tight and manhole construction of the best, to prevent infiltration. It must be recognized that the question of economics enters into the design of grades so that frequently it is more economical to design sewers which will require more attention periodically, than to strive for self-cleansing grades and pay the penalty of extreme depths and high construction costs, which naturally follow. In such cases, frequent manholes and flush holes make this later maintenance much easier. Manholes have frequently been added in later years at points where trouble has occurred. Although not generally recommended, this method of repairing defects in the original system is not without merit as it works somewhat in the same way that concrete pavements have been allowed to find their own planes of weakness.

The maintenance problem in a small city has been added to very frequently by poor early construction and a lack of proper supervision over plumbers when making house connections. The system of plumbing inspection in small cities leaves much to be desired in the way of supervision of connections with the sanitary sewer system and the fact that plumbing inspection in this type of city is very often a part-time job, taken care of by a plumber who is a competitor for this business in the city, is undoubtedly responsible for a great deal of sewer trouble. Probably the greatest handicap under which the small city labors is the fact that the size of the sewer system and the amount of new construction and maintenance carried on year after year, is not sufficient to allow the setting up of a full time organization for inspection and maintenance both of street pipe work and house plumbing. There is often a woeful lack of coördination between the work done on the street and work done on private property. A great deal of trouble has been experienced by the writer due to leaky house connections, surface water drains surreptitiously connected to the sanitary system and a general lack of care on the part of the plumber during that period of the construction when surface water, mud, etc., can readily reach the cellar connection to a sanitary system. This is a particularly acute problem in the smaller cities due to the fact that practically all sewers are local sewers of small diameter which are easily clogged if the slightest imperfections of construction occur, are easily surcharged if any appreciable quantity of surface water is admitted, and are hard to clean. Normal flows are so low that they have no power to carry away any unusual object which may find its way into the sewer either during the construction of the main, its branches or a contributing house or building.

The output of one industry, one hotel or a large garage amounts to such a large percentage of the total flow of a small pipe sewer that very often a serious problem arises. The writer has found small pipe sewers plugged solid for a distance of two or three hundred feet with sand and gravel from

auto washing racks where the settling devices provided for in the connection of the drains from such racks were not cleaned at sufficient intervals to prevent this matter from being carried to the street sewer. Pipes have also been found completely plugged by grease from restaurants whose grease traps were either inadequate or neglected to the point where they became ineffective. The solution of both of these problems is, of course, devices adequate in size for the removal of this matter and periodic cleaning of the same. The small city should insist on proper operation and installation of such devices. In Meadville we have been reasonably successful in having this done but there is still room for improvement.

Construction material, such as concrete, an occasional brick, a piece of 2 by 4 lumber, odd pieces of mortar, and similar things frequently find their way into a house connection during the construction of the building and eventually cause trouble in the house connection. A plumber is called and he rods the connection and moves the obstruction on out into the main sewer. A short time may elapse and trouble is at hand for the municipality. The next thing in order is the use of rods, flushing or a "dig up" job. This sort of trouble occurs so frequently in some small communities that they have become reconciled to it as a necessary evil in connection with new building. The plumbing code requires that house connections be made by registered plumbers but this is not sufficient guarantee of good work as the plumber himself very often has no conscience or any proper appreciation of the necessity for a good, tight job. Many good main sewer jobs have been spoiled by poor house connections and we are having a particularly hard time getting away from leaky cement joints in connections made to a sewer with good bituminous joints. It is also a fact that the addition of any trade waste, however small, may seriously affect a sewerage system in the small city. This is particularly true if only a small amount of certain wastes, such as unneutralized acids, creep into systems having small flows and small dilution. Acid sewage is, of course, disastrous where any iron pipes or pumps are involved in the system. One small community in the western part of Pennsylvania nearly lost an expensive iron line crossing under a good sized stream, due to this cause. Eternal vigilance is the price of freedom from trouble of this sort.

Small local sewer lines and trouble-making trees are very liable to go hand in hand in the type of communities under discussion. The root problem is an old one. Joints are being laid today which are more effective against the entrance of roots into sewers but the trouble is most frequently found in old lines on established streets where trees are of many years growth. In such cases all we can do is to remove them periodically and to hope they won't grow too fast. The writer has found the turbine cleaner on the end of a fire hose effective in case of slight stoppage but has found nothing to beat the windlass type of cutter, drawn through from

manhole to manhole, where the trouble is really serious. Various methods have been used to get the cable through an almost completely stopped sewer in order that this cutter can be drawn through, but wooden rods carrying a light line have been found most effective. Many cities have eliminated this type of trouble by removing the trees but some of the trees are worth enough to the city that it can well afford to put up with an occasional sewer stoppage. The city with a fine display of American elms is getting value received for the continued sewer trouble. The City of Meadville is very proud of its trees and we willingly face the responsibilities which they bring us. The property owner has been pretty well educated to the fact that the solution of his problem is iron pipe with lead joints and very seldom asks for permission to remove a tree in order to get relief. On new streets of less than usual width, we are insisting that the trees be planted back at least five feet from the sidewalk on the property side. This location places most trees a sufficient distance from the main sewer. On the older streets, experience has taught us something about rate of growth and we put a cutting tool through these old offenders periodically to avoid trouble. Of course, falling leaves offer an additional problem in connection with the street drainage system.

Not all cities find rags and newspapers stopping sewers but the writer has had occasion to have removed bundles of rags and newspapers tied up with strings in the form of a plug which just fitted the pipe and which had been very carefully inserted at a manhole by somebody with either a mean disposition or a rather peculiar sense of humor. This also applies to the party who found it convenient to dispose of the winter's accumulation of ashes in a manhole on an eight-inch sewer line, thereby filling it completely to street level. Mash from home brew is not particularly a problem in the writer's home city but in a few cases it has been troublesome and he understands that stoppages from such a source represent a considerable percentage of the total in certain sections of the state.

Proper maintenance of a small system involves several things. Periodic inspection of the entire system is necessary and, of course, in some cases, rather difficult. Fortunately, the larger lines seldom give trouble from stoppages. A little study and experience covering several years in any community will teach one where to look for the conventional troubles. Proximity of certain kinds of trees makes this source of trouble very apparent. Bad alignment and extremely flat grades are potentially such continuous sources of trouble that we can readily locate the cause when difficulties arise. Depths and known construction conditions will cause us to be suspicious of pipe failures. In order to care for all these troubles properly, a few good experienced men and proper equipment are necessary. A liberal supply of wooden rods fitted with a variety of tools, a good sewer cleansing machine of the drum and cable type, flexible steel rods and a

rotating nozzle of the turbine type, are all absolute essentials. Flush tanks at the end of sewer lines are not very effective. The same work can be done much more positively with a few lengths of fire hose and proper nozzles, where good water pressure is available. Of all the above appliances the turbine nozzle on the end of a fire hose started in at the lower point on a clogged sewer has saved the writer more street tear-ups than all the other devices added together. We have cleared pipes by this method which were packed solid for a distance of several hundred feet and have seen this device dig its way in and intermittently jerk the hose out of the hands of the astonished workmen until the nozzle had entered the sewer for a distance of two hundred feet or more.

A sewer only partly cleaned will give trouble again in a very short time. Circular wooden disks attached to the end of the conventional cleaning rods, when run through questionable sewers, have served to demonstrate their condition and prevent a false idea of the thoroughness of the cleansing job.

Sad experience has also taught us that immediate relief from a stoppage should not be the only end in view. Any article which causes a stoppage should either be intercepted at the next manhole and removed from the sewer or rodded and flushed until it reaches a flow sufficient to carry it the entire distance to the outfall. Sand and gravel or any grit of this kind is particularly hard to handle from this viewpoint and can be most successfully removed by the construction of a shallow dam or temporary grit chamber in an adjacent manhole at which point this material may be collected while flushing the sewer either from above or below. This has proven to be one of the most difficult tasks to get workmen to perform as material of this sort is hard to intercept and remove and the temptation is to get it into the larger line where it does not at the time constitute an actual stoppage but does decrease the capacity of the sewer, is an obstruction and may be the nucleus around which sufficient material will collect to effect an actual stoppage. The city will frequently be called upon to assist the plumber in opening house branches. A charge to the householder covering labor and water used for such service is proper and is made in the writer's municipality. The practice outlined above should be followed more frequently, rather than to pass the obstacle from the branch into a small main sewer.

Cleansing practice varies considerably in different municipalities but it is certain that some few fundamental practices must be followed by all. The flushing of flat sewers should be put on a time schedule so that they may be kept open instead of opened periodically by complaint of property owners. Sewers subject to trouble from tree roots should have some form of cleaner, of a diameter nearly that of the sewer, passed through the sewers from manhole to manhole periodically, in order to insure the use of the full

capacity of the pipe at all times. Various cleaning tools are on the market and many home-made ones are being used. This work allows the use of considerable ingenuity by the man in charge and many of these men have perfected devices which are admirably adapted to their local problems.

Tight manholes with noiseless covers are very desirable and almost necessary. The necessity for reducing infiltration to a minimum frequently makes it desirable to dig up old manholes, water-proof them on the outside by plastering or by the entire reconstruction of the manhole. Considerable work of this sort has been done in recent years. Covers which were very satisfactory 20 years ago are a nuisance today and positively dangerous sometimes due to their inadequate structural strength and the ease with which they are thrown out of the frame by fast moving traffic. They are very often noisy and the subject of many complaints. Covers have been deepened at the sides to prevent rocking in the frames and more heavily ribbed for additional strength. Rather wholesale renewal of old models makes up a considerable portion of the sewer maintenance budget in Meadville as well as in other small cities. In some cases it has been found possible to design new covers to fit the old frames. The old fashioned, lamp hole consisting of a tee and a riser pipe installed on a small pipe sewer has proven to be about the most useless appendage in the world. Many of them have been replaced either by manholes or a flush hole, built by installing a Y in place of the T and bringing the pipe to the surface at an angle of 45° with the horizontal, with the installation of a specially designed casting to cover this pipe. This change assists maintenance to a considerable degree as the inclined pipe can still be put to all the uses of the lamp hole and serves to direct the stream of water under high pressure into the main more nearly parallel to the line of flow.

One of the problems of the older cities having separate sewer systems has been the elimination from the system of roof water permitted to enter years ago. This has been a difficult part of the maintenance program, but is desirable for two reasons: first, the development of treatment plants has made it good business to reduce flows to a minimum; second, the growth of the city has made it necessary to retain or recover the entire capacity of these lines, which usually are small, to take care of the increased load from points farther up the sewer. This same need had necessitated a careful study of the problem of infiltration and has made necessary not only more care in choice of joint materials but the actual digging up and relaying of considerable lengths of line known to be leaking badly and in this way overloading sewers which otherwise would be adequate for the district served. Even in a strictly separate system it has been easy for a frantic official to solve a troublesome drainage problem by connecting just one surface drain to the sanitary system. Troublesome springs exposed during building construction and roof drains, where the curb or the

storm drain was not readily accessible, have been connected with the system while the plumbing inspector turned his back. In Meadville no street drains have ever been connected to the sanitary system but roof connections of long standing in the oldest parts of the city account for a peak flow during storms of from three to four times the average normal flow. This offers a rather serious problem to a city at present designing a treatment plant which is to be placed under contract this summer (1931) and where the entire flow must be pumped continuously. A survey has been started in an effort to isolate the sources of trouble with a view to forcing their removal at an early date, but it will be necessary to arrange all of the ordinary standby pumping equipment so that it can be used to handle this peak, until such time as the desired removals may be made.

Last, but not least of the items which make good maintenance possible, is the personnel involved. In the small city this will be small and will be composed of a group of men combining this duty with many others, but it must include a conscientious foreman, a couple of intelligent, handy men who are not afraid of any kind of a job, and any number of willing laborers that the job in hand requires. Such men are rare; our city nearly suspended business a few years ago when we lost a man who always had an answer for every emergency situation; who could arrive on the job in the middle of the night with a smile and still be able to smile after twenty-four or thirty-six hours of nearly continuous work under the worst possible conditions. It is desirable that proper personnel extend all the way up to the councilman or commissioner in general charge of the work, but this man is not always selected for his judgment or ability along this line.

This entire discussion might be summarized very briefly by saying: design right, build right, know your own sewer system, watch the weak spots, including the spots where economics are responsible for a compromise with what is generally believed to be good practice, watch your plumbing to the extent of inspecting the inspector if necessary, and your sewer system will operate so well that your public will be firmly convinced that your services are not needed to operate such a simple thing as a few sewer lines.

Discussion of Papers by Albert H. Mainwaring and Roy L. Philipps

Mr. Burnside: Those were excellent papers and I do not believe I could add anything of importance, but I did notice that neither gentlemen mentioned the matter of joint material. We have had considerable trouble in the use of materials for sewer joints. In the past two years we have adopted either the pressed or the prepared type asphalt joint. Mr. Young of Ohio has abandoned that after having used it. Roots would go through more freely than with a cement joint. They have gone back to the cement. We have ground water trouble and we have a brick clay formation which

is a miserable foundation. It is practically impossible to get tight cement joints under those conditions. I would like to know whether any others here have found that roots will go through. We found another difficulty. We have all types of grades from the flattest up to 20% grades and we find that on both flat and steep grades we get stoppages due to insufficient liquid in the sewage. Particularly is that true in the new districts. We have permitted the entrance of rain water, which flushes the sewers. This is permitted with the understanding that it can be and will be removed on order so that there will not be too many such connections. We had also a lot of trouble with sour mash, many times dumped into the sewers in sacks. That has been eliminated by the District Attorney, a strict prohibition enforcement officer, and a judge who is very severe. We have some combined sewers in our city built in a district which is largely hilly and which has many shallow streets. We have had trouble in the sewers from ashes. We have a large brick sewer which acts as a collector and we clean this out periodically, using a pumping machine. It crosses under the railroads and this cleaning is an expensive and mean operation. Other than that I do not have anything to add.

Mr. Baum—Altoona: In Altoona we have experienced trouble with infiltration. We found that by using bituminous joints we were able to exclude more ground water than by cement. We have used five or six materials for pressed joints but the outstanding material in wet ground is bituminous. We maintained an infiltration rate under 5000 gallons per mile in sizes of 8 and 12 inch. We have found no particular trouble where we have used bituminous joints. We doubt whether precast joints will exclude roots. We have found imperfect joints so imperfectly made that roots could pass between the two pieces of pipe. If terra cotta pipe could be made as true as is cement pipe, I believe it would be possible to use precast bituminous joints, because we have made joints which passed test. We carefully sealed the pipes to be sure we got a good joint. Bituminous joints are very tight joints. I believe they are sufficiently sound to exclude roots. They are very firm. If cement joints are perfectly made I doubt if you have trouble with roots and very little with infiltration but in most cases you can't obtain 100 per cent perfection in sewers.

President Beaumont: What is the relative life of bituminous joints?

Mr. Baum: We had a problem to find a joint for mine drainage. We took bituminous joints and laid them in effluent highly charged with sulphur water; it had no effect on them. We used terra cotta pipe for the sewers and "G. K." compound for jointing. We experienced no difficulty with this jointing material on terra cotta pipe. The sewage was so aggressive that in one manhole in the path of the flow of the mine water it ate through 1 inch of metal and the steel manhole was wrecked in about a month. We made tests to determine the flow from the mines, in which we

used small gauges, possibly $^1/_8$-inch size; they were corroded off in 10 days.

A Member from Pittsburgh: About three years ago we laid 20 miles of sewer, size 8 to 24 inches for a city in Ohio. We started out with bituminous joints but were asked to change from precast bituminous to the poured type. The poured type was better and cheaper. We have given thought to the matter of roots and while our experience is too recent to give us any information, I feel that properly made bituminous joints are almost impervious to roots passing through them.

Mr. Phillips—Meadville: We used cement joints for years with great success in certain locations, but no man can make good cement joints in several inches of water. I do not believe he could make a poured bituminous joint. There are other situations we found where probably we could use cement to advantage. Personally I am thinking about starting out with the poured joint. I would like to have some information about the joints used in Washington or Oregon. As far as acid is concerned, the Viscose Company installed in their plant a great number of feet of sewer for carrying off the wastes, which, I understand, are very acid, and they used asphaltic joints in those pipes as a result of a great amount of experimentation. They gave satisfaction.

Mr. Wickerham—Butler: I think the experience Mr. Phillips referred to was at Seattle. I do not know the size of sewer used but for various sizes they made molds and poured the bell and spigot and then repoured each of these. This was done above ground. Then when the time came to lay the pipe they treated this repoured material with an application of salt, which practically made the two pieces coalesce, and simply put the pipe in the trench and pressed it together with jacks. They had good results and tested up to 70 pounds pressure and had no serious leakage. As regards poured joints, I am quite sure it is possible to get a tight joint. It is a question of how much expense is justified in doing the work. It is surely a matter of construction. About three years ago the City of Columbus was laying some water lines where the test was up to 250 pounds. They used either cast iron or lead joints. A considerable portion of that line was laid in water to a depth of sometimes one-third the diameter of the pipe. In this case what was called a boat was made. This fitted the outside of the pipe and set in an excavation under the bell and of course joined the spigot. Then the water was pumped out. One of the necessary conditions is that you get your bell clean and practically dry before the pouring is made. I believe that line went up as far as 36 inches. In pouring up to a 30-inch pipe we have found that it is also possible to make a tight compound joint but the requirements are a dry bell and clean and dry spigot. Part of the line was laid in winter under severe freezing conditions, so the spigot end of the pipe was preheated so that when laid

it would prevent the poured liquid from coagulating. We did not have any appreciable leakage. Ninety per cent of what we did have could be accounted for from leakage in the manhole. Another thing to remember is that your compound is liquid and therefore you have to maintain hydrostatic pressure. This caused no trouble up to 15 or 18 inches but when up to 30 inches we found trouble. To correct this we got bands and strapped them about three-quarters of the way around the pipe.

Operation of Trickling Filters at Baltimore*

BY HERMAN KRATZ, JR.

Junior Chemist, Back River Sewage Treatment Works, Colgate, Baltimore County, Maryland

Thirty acres of trickling filters costing $1,519,336 are used to treat the effluent from the primary settling tanks at the Baltimore Sewage Treatment Works. A considerable amount of experimental work was done before the filters were built to determine the best method of treating the settled sewage. The work was done about twenty years ago, and as a tribute to it, the Baltimore filters are still functioning with a high degree of efficiency.

Many results are effected by treating the settled effluent on trickling filters. The action of the biological processes in the film upon the stones is remarkable, in view of the brief period of time required for treatment, averaging only 20 to 30 minutes. Colloidal substances are removed from suspension, the bacterial content is greatly reduced (90%), organic matter is rendered less putrescible, and nitrogenous compounds are oxidized to nitrites and nitrates.

Other devices are used in conjunction with spraying the settled sewage on the stone and the best manner to describe them may be to discuss the units according to the order in which the sewage flows, with particular attention to special features of the Baltimore plant.

Revolving Screens

After sedimentation, the sewage passes through cylindrical revolving screens 10 ft. 2 in. long and 12 ft. in diameter. They are covered with Monel metal cloth having 20 meshes to the linear inch. These screens remove most of the solid material, which passes through the settling units. Matchsticks, lumps of grease and other light materials are the principal causes of nozzle stoppage, and the fine mesh screens effect the removal of almost all of these substances. Before the screens were built it was necessary to clean each nozzle several times a day; now approximately 300 nozzles are cleaned daily, which represents but little more than five per cent of the total (5830).

Control House

From the revolving screens the sewage flows to what is sometimes called the "Constant Head Chamber." This compartment is under the floor of a building known as the "Control House," and serves as a distributing chamber to the filter beds.

* *Presented before the Fourth Annual Conference of the Pennsylvania Sewage Works Conference, State College, June 27, 1930.*

Ten electrically operated valves with stems extending above the floor of the control house are set into the bulkhead of the chamber. Each valve is attached to a conduit which carries the screened, settled sewage to three acres of the filter area. At low flow about four beds (12 acres) are sufficient for filter treatment; when the flow increases, additional beds are brought into service by opening valves connecting with unused sections. As the flow decreases, usually at night, the elevation of the sewage surface drops. Units are then taken out of service so that a fairly constant head is maintained. Disregarding pipe friction, there is about $12^1/_2$ feet of head on the nozzles.

Butterfly Valves

Leading from the control valves are 18 × 27-in. castings, through which the sewage flows on its way to the nozzles. Inside of each casting is an iron plate (called a butterfly valve), rotated on its horizontal axis by a shaft extending through a stuffing box to the outside of the housing. This plate neatly fits the inside of the casting with a clearance of about one-half inch. Gearing connects the shaft to a one horsepower motor. The plate is turned through one revolution (2 cycles) every seven minutes (approximately), thus alternately damming and releasing the sewage flow to the nozzles. The slow speed is accomplished by means of a reduction gear attached to the motor, which drives the ten butterfly valves. The spray on the filters under this action falls first on the stone immediately adjacent to the nozzles when the valve is in the perpendicular position, the spread gradually increasing to a distance of $7^1/_2$ feet from the nozzle, by the time the plate has reached a horizontal position. At this point the maximum amount of sewage is flowing.

Conduits and Laterals

To lead the sewage to the separate beds, conduits have been constructed parallel to one side of the filter area, which is rectangular in shape and approximately 800 by 1760 feet in size. Each conduit makes a 90° bend to divert the sewage through the center of the bed onto which it is to be sprayed.

Beneath the filter stone, lateral pipes are connected with the conduits. Riser pipes carry the sewage upward to the nozzles. Laterals and risers are so constructed that the nozzles are spaced at the corners of 15 feet squares.

Nozzles

Three types of nozzles are in use, namely, the Columbus, Merritt Square Spray and Taylor Clover Leaf. Each has a three-quarter inch discharge opening, and the stems of the deflector plates of the latter two types are

3/8-in. in diameter at the bottom end. One bed of three acres is fitted with Columbus nozzles whereas the remainder of the filter area is equipped with Merritt and with Taylor nozzles. In December, 1927, 200 additional nozzles of the Columbus type were purchased at the cost of $300 and were placed in service early in 1928.

Stone

Eight and one-half feet of trap rock, one to two and one-half inches in size, constitute the filter medium. The stone was quarried at Havre de Grace, Maryland, and has proved to be very serviceable.

Clogging or pooling has never occured, and no special preventive treatment is given the beds. Before the plant was designed, the Board of Advisory Engineers in their report of May 31, 1906, stated, "The self-cleansing feature of sprinkling filters has already been mentioned, and in our cost estimate we have assumed that they (the stone) would require removing, cleaning and replacing on an average once in ten years, which from some European experiences may be too short" and $19,000 was estimated to be allowed for this purpose. There are no indications that this will ever have to be done.

Shrinkage of stone volume has been anticipated but there are no visible indications of any loss in volume. Recently a small amount of stone dust has been removed from the final settling basins, which treat the filter effluent. Considering the 20 years of service, the stone apparently is still fit for several decades of use without any alterations or changes.

The efficiency of the beds declines considerably during the sloughing period. This semi-annual phenomenon of the stone shedding its film covering, is probably caused by change of temperature since this condition habitually occurs in the spring and fall of the year. The loss of the jelly-like film causes a drop in the efficiency of the filter, and during this period the stability of the effluent is comparatively low. The effect of sloughing is evidenced by the inferior quality of the effluent over a period of one to two weeks. Following the sloughing period, the film gradually re-establishes itself upon the stone, and this change is reflected in the character of the effluent by a gradual rise in the stability curve until the maximum efficiency is reached.

Drains

The floor of the filters is of concrete and constructed with half-oval shaped gutters covered by slotted terra cotta plates. The gutters collect the filtrate when it reaches the bottom of the stone. Two main drains passing through the center of each bed then receive the discharge from the gutters and carry the effluent to the main channel which serves all beds.

Walls

Three walls of the filters are of concrete. The fourth, that adjacent to the effluent channel, is of dry rubble masonry. Concrete pilasters are inserted at intervals to prevent stone falling out and side slip of the large rock used to retain the filtering material. Rubble masonry was used to permit additional breathing of the beds by allowing more air to circulate through the stone, and thus accelerate oxidation.

Flow and Manipulation

The average rate of filtration is about 2.75 million gallons per acre per day. This rate is based upon the actual operation time of each bed and not on the total of 30 acres. Since the entire area is not in constant use, the operators rotate the beds in service so that each section is worked about the same length of time throughout the year. Beds which remain idle after a long period of service, give off foul odors due to the decomposition of the film covering of the stone. Upon being replaced in service, the idle beds are less efficient than those in regular use, and this condition prevails until the stones again become coated with bacterial jelly. As described above, efforts are made to keep all the beds in good condition.

TABLE I

TRICKLING FILTER OPERATING DATA

Year	Sewage Flow, Million Gallons		Cost of Filter Operation	
	Total	Rate of Filtration per Acre per Day	Total	Per M. G.
1925	20,108.30	2.78	$13,483.48	$0.671
1926	21,368.45	2.71	15,583.68	0.729
1927	21,762.08	2.79	13,608.66	0.625
1928	23,237.38	2.75	14,276.39	0.614
1929	22,745.02	2.74	13,520.84	0.594
1930	22,138.61	2.60	14,107.30	0.637

Baltimore uses separate sewers to collect its sanitary wastes. The average daily rate of flow is 60 to 65 m./g. with a minimum of 30 to 35 m./g. and a maximum of about 90. During severe rainstorms, prolonged wet periods, and rapid thaws of ice and snow, these flows are often considerably augmented. Abnormal conditions have caused peak loads of more than 150 m. g. d.

Cleaning

Two men clean nozzles during an 8-hr. period each day except Sunday, when only one man works. The flow to the bed to be cleaned is reduced by partly closing the control valve and allowing but a small amount of sewage to be discharged from each nozzle. This operation permits access to the nozzle without wetting the filter attendant, and at the same time the dirty nozzles can be readily detected. Cleaning usually consists of unscrewing

the nozzle from the riser plate, shaking or tapping out the obstruction and replacing the cleaned nozzle. In cold weather, grease tends to collect on the deflector plates, and occasionally a stiff bristle-brush is used to remove this accumulation.

Lateral pipes are cleaned by flushing. The end nozzle on the lateral is removed while the bed is receiving the full flow. After a few cycles of the butterfly valve, the nozzle is replaced. Originally the lateral ends were equipped with flushing hydrants in the galleries separating the beds, and by means of a hose connection, the laterals were to be back flushed. This procedure is unhandy and good results are had by merely removing the end nozzle. The flushing hydrants were also intended to be used as a source of supply for flushing the underdrains of the filters. It has never been necessary to use them.

In severe winter weather ice collects on the surface of the stone at the extreme perimeter of the spray, but there is no interference with the regular bed operation. To prevent risers and nozzles from freezing, the control valves to idle beds are slightly opened to permit a small flow of sewage onto the beds. In extremely cold weather pipes of idle beds are drained to eliminate any possibility of freezing.

Filter Fly

Filter flies (*psychoda alternata*) are present in warm weather, and formerly efforts were made to destroy or control the pests. Flooding cannot be resorted to since the south wall of the filters is of rubble masonry. Several schemes (including chlorine) have been tried but no marked results have been obtained. For the past few years the flies have not been very conspicuous, due possibly to large numbers of starlings which feed on the beds at certain seasons of the year. At present the filter fly is not a serious problem.

Foam

Considerable foam has been produced in the filter effluent channel in recent years. Chemical analyses indicate that a large percentage of the foam is grease. Globules resembling minute collections of oil or fat have been reported from microscopical examinations of the film on the stone. Probably oleaginous compounds are coagulated within the filters, which are later released in the form of foam. At present the foam is skimmed off and retained in a lowland ditch where it is quickly digested since the solids are small particles.

Experiments

Numerous investigations have been conducted on the filter beds, most of which were of a mechanical or hydraulic nature. Notes from some of the experiments are given below.

Nozzles become damaged from long usage and the deflector plates often become bent or disfigured. To restore uniform distribution a few Merritt Square Spray nozzle deflectors were turned down from a square $2^1/_2$ inches on a side to a circle $1^{13}/_{16}$ inches in diameter. This change produced a higher spray that apparently covered the stone better than the Merritt or Taylor nozzles. Filter attendants reported that the remodeled nozzle clogged less readily than the others, but because of its circular deflector plate, was more difficult to remove for cleaning. Although it seemed that this latter difficulty might interfere with the adoption of the remodeled nozzle, it showed sufficient promise to warrant further investigation.

Tests carried out covered two features, namely, a study of the distribution efficiency and the probable effect on the filter effluent. A large volume of data was collected but only the conclusions will be noted here. The Merritt remodeled nozzle gave the best results for coefficient of distribution, and the flow was greater than that through the original Merritt nozzle.

If all the beds were equipped with remodeled nozzles, there would be a possibility of decreased efficiency. To determine the possible effect of such a change, one bed was fully equipped with Merritt Square Spray nozzles and another with Taylor nozzles. The Taylor nozzle was selected since its volume of discharge approached that of the remodeled nozzle better than any of the others then on hand. Furthermore, it was not advisable to alter about 600 nozzles without first knowing the results to be expected.

Before making the chemical study of these beds, all nozzles were thoroughly cleaned and straightened so as to present comparable conditions. Both beds were then placed in service and were not stopped for a period of one week during which time samples were taken hourly.

The results indicated that the bed with Taylor nozzles produced an effluent slightly inferior to that equipped with the regular Merritt nozzles. Since the Taylor and remodeled Merritt nozzles discharged a greater volume of sewage than the original Merritt nozzle, the conclusions were that for the same volume of sewage, the remodeled nozzle would be satisfactory.

Another experiment, probably of interest, was made to compare efficiencies obtained with various rates of flow. One bed was calibrated by coupling a box to risers, and measuring the flow through the nozzles, which were attached inside the box. This container was about 30 in. square and 36 in. high. The bottom was fitted with a riser cap-plate, into which the nozzles were screwed. The cap-plate also served as a means of fastening the box to the riser, bolts being passed through the plate and box bottom and then through the bottom riser plate. To confine the spray to the box, a horizontal sliding board was used as a top and was kept closed while flow measurements were being made. At the bottom of one side there was a 6-in. square opening and the flow through this hole was measured with buckets.

The bed was dosed with sewage at the following rates, 1.0, 1.5, 2.0, 2.5, 3.0 and 3.3 m. g. a. d. One million was found by trial to be the minimum rate at which the control valve would satisfactorily regulate the flow and 3.3 m. g. was the maximum rate obtainable. Samples were collected every three hours for a period of seven days for each rate of flow. The results indicated that the efficiency of the bed increased in proportion to the rate. Above the maximum rate (3.3 m. g. a. d.) it is problematical to what extent the proportion would hold.

Analytical Results

The settled sewage contains about 1,500,000 bacteria per cc., 500,000 being acid formers. The filters effect a removal of approximately 80 per cent of the total organisms and about 90 per cent of lactose fermenters. Analytical data are shown in Table II.

TABLE II

ANALYSES OF EFFLUENTS OF SETTLING TANK AND TRICKLING FILTERS

	Settling Tank Effluent			Filter Effluent				
Year	Solids Suspended, P. p. m.	Solids Settling, P. p. m.	Biochemical Oxygen Demand, P. p. m.	Solids Suspended, P. p. m.	Solids Settling, P. p. m.	Biochemical Oxygen Demand, P. p. m.	Nitrates, P. p. m.	Relative Stability Number
1925		29	109		38	26	5.5	87
1926	55	24	100	42	25	24	6.1	96
1927	60	26	112	48	27	27	5.6	90*
1928	51.5	18	88	33	18	17	4.9	98
1929	65	18	98	39	20	28	5.9	97
1930	60	19	116	34	20	29	7.8	95

* Prior to 1927—0.10% Methylene Blue Solution Used.
Beginning 1927—0.05% Methylene Blue Solution Used.

The settling tank effluent contains no dissolved oxygen and no completely oxidized nitrogen (nitrates). After filtration, however, dissolved oxygen is present in varying amounts, the nitrates average about 6.0 p. p. m., and the stability has increased from practically zero to about 95 on the average.

B. L. Crozier is Chief Engineer of the Department of Public Works, Milton J. Ruark is Sewerage Engineer. C. E. Keefer is Engineer of Sewage Disposal and G. K. Armeling is Superintendent of the Disposal Plant.

Industrial Wastes and Stream Pollution

Admission of Industrial Wastes into Sewerage Systems*

By H. M. Freeburn

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In Pennsylvania, state law requires approval by the Sanitary Water Board of plans for sewerage systems and sewage treatment works. The Sanitary Water Board either issues or refuses approval permits for such plans, subject to certain conditions, after engineering studies have been made and reports received from the Bureau of Engineering, Pennsylvania Department of Health. A standard condition of sewerage permits relating to the admission of industrial wastes into separate sewerage systems is as follows:

No storm water from pavements, area ways, roofs or other sources shall be admitted to the sewers herein approved, which shall be used exclusively as carriers of domestic sewage and *suitable industrial waste.*

When plans for a combined system of sewers are approved, this condition is modified.

Although the Sanitary Water Board stipulates that sewers shall be used exclusively as carriers of domestic sewage and suitable industrial waste it should be borne in mind that a great responsibility rests on the shoulders of local authorities, who by law have charge of the sewer system, as to whether or not the industrial waste will be received or excluded.

Naturally, when a new system of sewers is to be constructed in a community where there are existing industries, the question immediately arises as to what is a suitable industrial waste to admit into the sewers. This is a problem that should be studied by the designing engineer, giving due consideration to the characteristics of the waste as well as the quantity and rate of discharge to the sewers. The information disclosed by a thorough survey of industrial wastes may govern the type of sewage treatment processes adaptable to the conditions.

Next, there is the question of a new industry proposing establishment in a community and the resulting problem as to whether the industrial waste from the factory or plant should be taken into the existing sewerage system.

Then there is the case of an established industry requesting a com-

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munity to extend its sewer system to receive industrial waste that was being discharged untreated into State waters or possibly being passed through an inadequate industrial-waste treatment plant, thus creating a stream pollution and nuisance.

Other questions and complications also arise in connection with the advisability of admitting industrial waste into sewerage systems.

Usually the executives of an industry, who are accustomed to making prompt decisions, want a prompt answer to their proposal about a sewer connection, and they are entitled to a clear cut decision without any great delay.

Industrial waste disposal is rapidly coming to the front as one factor for consideration by industrial executives when they consider the establishment or the abandonment of an old plant for a new location. It can be seen that this question is of vital importance to communities as well as industries. If the problem is not met fairly and squarely it may mean the loss of an existing industry or the loss of a new industry which in turn means loss of taxes and possibly the difference between prosperity and business depression in the town.

There are many kinds of industrial wastes and the proposition of giving a quick "yes" or "no" answer is difficult. The correct preliminary answer, and the one often given by engineers, should be, "It depends." This reply is given because an investigation is often needed before the engineer can give proper advice.

Before arriving at a way of handling these problems and setting forth certain fundamentals about industrial waste admission or exclusive from a sewerage system, it is well to recognize that most industries are an asset to a community as a taxpayer, and usually a big one, and also, and by no means least, as an enterprise which gives employment to citizens.

For the purpose of this discussion industrial wastes can be divided into four classes:

Class 1.—Those that can be admitted to the sewerage system without any preliminary treatment.

Class 2.—Those that can be admitted to the sewerage system after flow adjustment without any preliminary treatment.

Class 3.—Those that can be admitted to the sewerage system after they have been given preliminary treatment.

Class 4.—Those that should be excluded from the sewerage system.

Class 1

Industrial Waste That Can Be Admitted to a Sewerage System without Any Preliminary Treatment:

1. When it does not throw an undue burden on the other taxpayers by materially increasing sewer maintenance and sewage treatment works operating costs.

2. When it has no injurious affect on the sewers or the receiving body of water.

3. When it does not materially affect the existing or proposed sewage treatment processes.

In other words industrial waste that is discharged at a fairly uniform rate and does not differ greatly from ordinary domestic sewage, nor constitute a large per cent of the total flow, could be admitted to sewers and sewage works without doing any harm. When industrial waste flows are high as compared to sewage flows you may ordinarily look for trouble at the sewage treatment works.

Class 2

Industrial Waste That Can Be Admitted to a Sewerage System after Flow Adjustment:

Wastes, such as those that do not materially differ from sewage, and those that are much stronger than sewage, which are released in large volumes over short periods of time can usually be taken into a sewer system after the flow has been equalized and discharge made at a reasonably uniform rate.

Sudden large discharges of industrial waste should not be allowed.

Class 3

Industrial Waste Requiring Preliminary Treatment:

Industrial wastes, such as the following, that cause objectionable conditions should not be admitted to sewer systems unless the producer provides satisfactory treatment:

1. Wastes which contain substances that will form deposits in the sewers or stick to the inverts.
2. Those containing excessive amounts of fats or oils.
3. Acid wastes that injure joints, concrete, or seriously interfere with treatment processes.
4. Wastes very much stronger than ordinary sewage.
5. Wastes having high solid contents that will overload treatment works.
6. Wastes that create offensive odors at treatment works.
7. Wastes having an inhibitive effect on bacterial and biological activity at the treatment works, thus decreasing efficiency.

Class 4

Wastes That Should Be Excluded from the Sewerage System:

1. Live steam
2. Scalding liquids
3. Illuminating gas
4. Exhaust gases
5. Gasoline
6. Oil

7. Wastes having a low oxygen demand, with a high solid content that can be removed at the industrial establishment, should be treated there and the effluent discharged to a nearby storm sewer or watercourse, if available.

8. Strong acid wastes should be reclaimed.

9. Weak acid wastes should be neutralized and discharged to the nearest watercourse or storm water sewer.

10. Wastes discharged in such large volumes that they predominate over the sewage received at the sewage treatment works, especially if the discharge materially increases operation costs or seriously interferes with treatment processes.

It should be borne in mind that the foregoing examples are by no means complete and that it is almost impossible to set forth practical hard and fast rules concerning the admission of industrial waste into sewerage systems. Each case should rest on its own merits.

When plans for new sewer systems are being prepared the consulting engineer should make investigations at the existing industrial plants that produce liquid waste and consult with state authorities concerning admission to the sewerage system.

When problems arise about the admission of industrial waste to existing sewerage systems it is a wise plan to recall the designing engineer, or some other qualified expert who is familiar with local conditions, to study the case and advise the owners of the sewers after consultation with state authorities.

Manufacturing processes change from time to time, because an establishment must make new products to meet competition and because styles change. New manufacturing processes may completely change the character and quantity of industrial waste produced. To take care of changing conditions, agreements should be made concerning the character, quantity and rate of flow of industrial waste that may in the future be delivered to the sewers. These agreements should provide for exclusion of the waste from the sewers, for preliminary treatment, or for additional preliminary treatment, if the industrial discharge proves to be deleterious, or threatens to become deleterious, to the sewerage system, the sewage treatment works, or the receiving body of water. If a fee is paid to discharge waste to the sewerage system the parties have entered into contract relations; if no agreement has been made, it would be very difficult legally to compel any later treatment, or changes in treatment, of the industrial waste. In such a case the owner of the system, usually the municipality, would have to bear the burden at the sewage treatment works.

It is always wise to keep industrial waste separate from the domestic sewage prior to discharge into the public sewerage system. It is also wise to keep unpolluted cooling and condensing water separate from the plant

domestic sewage and industrial waste. Usually there is no need for treatment of this water and it can be discharged to the nearest storm water sewer or water course.

In many cases industrial waste problems are approached primarily with the sole idea of making money by reclamation of by-products, placing the proper treatment or disposal of the waste in a secondary position. The reverse should be true. There should be an end to the cry that nothing can be done because the industrial waste treatment plant will not pay for its operation or yield an income. Search for methods of reclaiming by-products is commended, but officers of industrial establishments should consider the proper disposal or treatment of waste from their plant to be just as essential as any one of their manufacturing operations.

Investigations should be made at every industrial establishment to determine the character, quantity and rate of discharge of industrial waste from each manufacturing process. It may be found that the waste could be discharged into a stream without any treatment, or on the other hand, it might be found that only a small part of the waste needed treatment. Then again it might be found that the volume of waste is so small that it could be taken into the sewer without any treatment or that only an equalizing tank is needed to distribute the flow of waste over a 24-hour period.

Much can be accomplished in the way of industrial waste treatment by coöperating with industry and explaining the reasons for certain requirements. Lay your cards on the table and ask for help and assistance. If you cannot secure coöperation by peaceful methods after a reasonable time, then go to war, but before you start a battle consult with the state authorities. If you are right, fair and just, and have properly presented your case showing the need for industrial waste treatment to the responsible industrial plant executives, there will be little need for a battle.

Some of the main factors needed to solve industrial waste disposal and treatment problems are:

1. Facts,
2. Sound engineering,
3. Clear explanations why you are asking for certain action,
4. Coöperation with industry,
5. Patience,
6. Sound legal advice,
7. Use of common sense.

Discussion

President Beaumont: We are considering one treatment of sewage where the acid was diluted by mixing with other wastes.

Mr. Siebert—Pennsylvania Sanitary Water Board: This paper was of particular interest to me in connection with the sanitary survey of streams conducted by the State Sanitary Water Board in the past two years under my supervision. We have a detailed investigation of probably 1600 individual establishments discharging industrial wastes. It is to our advantage and to the advantage of the industrial establishments that the wastes, whenever possible, be discharged to the public sewer system by economical and logical methods. There have been some instances in which the coöperation of the municipal authorities has not been forthcoming to bring about the discharge of proper industrial wastes to sewage treatment works. It makes it hard for the state, if municipal authorities are hide-bound and object. There are not many cases, but some. As Mr. Freeburn emphasized, it is to the benefit of the municipality to encourage industry in every legitimate way, and if at all possible, recognize the propriety of taking care of those industrial wastes which are not prejudicial to sewers. Certain acid and alkaline wastes when dumped together neutralize each other before any harm is done. The discharge of acids and alkalies from different establishments or in different departments of the same establishment, are often so intermittent that a large alkaline discharge will pass down without an opportunity for an equivalent acid discharge to mix with it and be rendered harmless. We found in our investigations and studies that it is important to have the mixture, neutralization and sedimentation of these acid liquids where they are discharged by the same or nearby plants. We try to secure coöperation by bringing one industry with another to effect neutralization. These things are all probable, but we do suggest that you should not be content with a single investigation. These conditions are so today and entirely different next month. The processes change. Investigations must be kept up to determine if conditions are the same as a year ago, or they may get ahead of you and damage be done. Our practice is to make quite thorough investigations, with chemical analyses of all waste waters in any area or given territory in which we are working. On the Schuylkill River we have made approximately 747 from near the limits of Philadelphia to and including Reading. On the Delaware and Lehigh Rivers there are approximately 500 establishments, running from the little Chinese laundry up to large steel works, gas works and coke plants. Our purpose is to get as many of these into the sewer systems as possible, provided they do not work any damage. Do not forget to keep after them.

Mr. Wise—Connecticut State Water Commission: I come from a state highly industrialized, consequently the subject is of considerable interest to us. I might mention that the question of discharging industrial wastes into sewers is one on which we have spent time and quite a lot of effort in securing appropriations to carry on research work in the treatment

of the wastes of each industry. We are familiar with a number of instances where the discharge of industrial wastes into sewers has proved very disastrous, particularly to sewage treatment works in which bacteriological processes are employed. I feel it to be economical to have each industry treat its wastes individually and so we have the Chemical Engineering Department of Yale working on certain particular problems, and a department of another university working on chemical and other industrial wastes. I am anxious to learn what success they have had in Pennsylvania where they discharge industrial wastes into sewers, whether in any particular instance it was disastrous to bacteriological treatment of sewage. In Worcester, Massachusetts, they have a considerable amount of metallurgical liquors. They are anxious to get them into their sewer system for they have considerable alkali. They are trying to find an economical way of treating metallurgical liquors.

Mr. Siebert: In regard to industrial wastes, their character and quantity. We do not advocate the discharge of certain wastes to sewers and I would not expect a small city to accept them. For instance, I find that paper mill wastes raise havoc with small treatment works. We in Pennsylvania believe that in very many instances, with appropriate scientific study and with control—not without control—and with such preliminary treatment as is indicated, the discharge of a reasonable amount of waste waters to the sewer system is much more economical for everyone concerned than general private treatment.

Mr. Wickerham—Butler: This brought the question to my mind as to whether or not this problem does not put another burden on the shoulders of the planning engineer or the zoning commission of municipal councils. If the city planner would have these facts and could attend these meetings and realize what possibilities there are in the proper location, or rather zoning, of a district in order to facilitate and assist different industries, one having alkali and one acid wastes in close proximity, so that they can be economically taken care of and mixed before entering the sewer system, it might help to a considerable extent.

Mr. Fales—Metcalf and Eddy, Boston: I refer first to Worcester where I got my first experience. The treatment originally adopted was chemical precipitation and it was adopted because of the pickling liquors and acid iron wastes. It was of great benefit so far as coalition was concerned. The pickling liquors came down in doses which made it necessary to use large quantities of lime so that the actual cost of treatment was a great deal more than usual. As soon as we got away from chemical methods of precipitation, it was a great hindrance and the standard of purification was affected; when they came to try out activated-sludge treatment, great doses of iron came down and it was impossible to run the activated-sludge plant. They went ahead and designed an Imhoff tank and trickling-

filter plant under conditions prevailing at the time Things went well until business was so good, both in the tannery where the alkaline wastes were produced and in the wire mills where the pickling liquors were produced, that such large volumes of iron were precipitated in the Imhoff tanks, so that there was no room for sludge digestion. More recently the depression in business has helped that condition.

Mr. Laboon—Pittsburgh: I believe, in accordance with Mr. Fales, in classification perhaps going a little further than he did. I would say that where it does not place an undue burden on the other taxpayers, industrial wastes when they are of such quality that they will not injure the sewers or seriously interfere with treatment processes, ought to be taken into the sewers. We always consider it our duty in designing a sewage treatment plant to make an industrial survey and decide what wastes should go into the sewers and what ought to be excluded from going in.

Mr. Fales: In Akron we made a thorough investigation of wastes from rubber-reclaiming plants. These wastes contain more suspended solids than all the sewage of the city. City officials were told the design of the plant must be governed by the policy of the city in reference to taking wastes in the sewers. Sludge digestion was seriously affected and sedimentation was affected. We proposed that it would be equitable to remove the bulk of those solids, leaving even then a large amount of dissolved substances to add to the sewage, which would considerably increase the burden; we designed the plant on that basis.

Akron's plant has been greatly overloaded with solids. One condition you have to bear in mind, as Mr. Laboon said, it is easier to say than to accomplish.

The Fostoria, Ohio, plant was designed to take care of sewage and was well designed by the engineers, but we were called in because the plant had fallen down because of industrial wastes. It was quite a task to get city council to require certain wastes to be treated and certain to be excluded. That has been done, the plant fixed up, and is working well. Politics play a part here. We do not know what political changes will be made but if the wastes are put back history will repeat itself. We ought to encourage industry as much as we can but get the conditions settled before we go ahead and put a plant in operation. Trouble is avoided at the outset by having industrial wastes studied and properly separated.

Another instance was at Paterson, N. J. Silk dyeing industry wastes were put into the sewers. The sewers became blocked and sewage and industrial wastes overflowed into the river. Injunction proceedings were brought against the city on account of the pollution of the river and there our problem was to take out of the sewers a good part of wastes that never should have gone in.

Mr. Yeager—Philadelphia: In Philadelphia we have a Commission

in connection with our work. We investigate the troubles of plants. If an industrial plant has trouble and it seems to be a question as to whether the effluent would be objectionable, the permit division refers it to the engineering division for investigation. There it is referred to me and I take my crowd out and sample their wastes, and if after analyzing them I find they are objectionable, the only thing to do is to go back and find out if we can neutralize the effluent without any extra cost. Sometimes the wastes are combined with other wastes and oftentimes that suffices. In the various plants I have in mind there is an industrial alcohol plant. That is very easily taken care of. The main trouble is coöperation. I don't have any trouble if I can show the general managers that it is to their advantage to coöperate. If they don't, it means increase in taxes and increase in the cost of treating sewage. When you talk taxes, you talk turkey. They will hand you everything you ask for within reason. I have not been refused coöperation once, but as was stated, you want to be sure of your ground before you move. The other plants you encounter have their difficulties: dyeing plants and bleaching plants are two I have in mind. There are high acid and high alkali discharges. These plants are neighbors. The alkali came in contact with the acid and therefore the acid had little or no chance to operate on the sewer structure.

President Beaumont: In Philadelphia there is practically no legislation as to the discharge of material which will cause deposits. As to the exclusion of steam and hot water, in that we have no legislation dealing directly with the plants. We should go to the legislature and persuade them to do their part toward taxpayers.

Mr. Ryan—Rochester, New York: Do you try to get the color out of alcohol wastes?

Mr. Yeager: We do not make any effort to get the color out as long as we get the acid out. We have known of fruit juice wastes which are not necessarily acid when they reach the sewage plants but which when mixed with solids, become acid. In the treatment of acids the sample bottles will tell you.

Mr. Freeburn: One point is clearly shown; proper agreements and permits should be made and given to industries prior to their going into the sewer system. Another thing, when these investigations are made you can't depend too much on what an industrial establishment is going to discharge into the sewer system and whether they are going to discharge the same thing they were discharging out of their industrial treatment plant.

Another thing: these days everybody is saying, "pass a law" and the statute books are so full of laws now that most of them are not being enforced. I believe if you go about this problem in the right way, you can get what you want. Concerning local political situations, the State De-

partment can, in many cases go into a community and overcome those local political difficulties.

Mr. Wickerham: I sometimes think the final burden must be borne by the designing engineer. We will have to design plants that will take care of industrial wastes. Get the industry to agree to contribute its share in the total cost of the plant that will take care of industrial wastes no matter what their future conditions will require them to deliver to the sewer system and design the plant accordingly.

Control of Cannery Odors at Monterey*

BY H. D. SEVERANCE

City Engineer, Monterey, California

Monterey has ten sardine canneries and one municipal rose garden. The canneries seem to hold the vital interests of those who labor or trade; the rose garden the rather passive enthusiasm of those who neither toil nor spin. The unpleasantness of the one is tolerated or condoned by those sustained by it in their eagerness to secure wages and profits. The pleasantness of the other is lost to those who do not have or do not spare the time for its intimate contact or observation. The one spreads its odor a mile or two; the other spreads its fragrance perhaps a yard or two. The one was developed by the method of trial and error through a period of thirty years, while the other was developed by the same method through a period of ten thousand years. Wherefore, let us be patient.

Monterey was a whaling station at one time, but I find nothing in the archives to indicate a very strong public sentiment in reference to odor matters. This accounts for the traditional tolerance of our native stock. In fact, an old timer, speaking as to healthfulness of the trade, told me that the rendering of blubber on the kitchen stove would prevent anything but a large family.

About 1901 marked the beginnings of our sardine industry. The primary purpose was the canning of fish, about five hundred cases being the first annual output. Now we produce about one and a half million cases. About the time of the war it was discovered that the waste, or by-products, offered greater profits than the canning of fish for food. Then began the rush on the part of all hands to install reduction plants to take care of the waste products, cuttings and so forth, which in the early stages were practically thrown away. It is significant that while the canneries were not particularly sweet smelling establishments prior to this time, there was little annoyance to the citizens generally over the town, since the odors were local and did not travel far. Except during the stay of a reduction ship in our harbor, which was evidently carrying on experiments for the production of atrocious smells, no serious annoyance was created until the installation of high temperature rotary driers. Real trouble was then in the air, in and about town, when all the plants were working to and beyond capacity with machinery that was breaking down, with the resulting burning of the fish meal. We began to wonder if this was all necessary, and finally decided to stop the whole business.

Well, how do municipalities put a stop to such nuisances? By passing an ordinance, of course. This was done. Ordinance No. 106 says,

* *Presented before the Fourth Annual Meeting of the California Sewage Works Association, Monterey, Sept. 22, 1931.*

"It shall be unlawful for any person, firm or corporation to suffer, allow or permit any unwholesome, offensive, disagreeable, nauseous, or obnoxious smells, odors of gases to arise, emit, escape or be discharged from any fish cannery, fertilizer works or other works or other establishments within the corporate limits of the City of Monterey."

That did the trick so far as the record was concerned. That's all that could reasonably be expected from a legislative body. But we were still annoyed and nauseated and were acquiring a bad reputation abroad. We, as enforcement officer, hesitated to go into a man's cannery and accuse him of producing bad odors. We would get into an argument and the chances were good that we would apologize and leave convinced that the bad odor must come from the other nine canneries. This merry-go-round was indulged in for several years with no noticeable cessation of odor.

I pause here for a moment to ponder the reaction of the public so far as enforcement of ordinances and laws is concerned. We are all more or less agreed that the law against counterfeiting must be enforced. As to most all other laws there seems to be a wide diversity of opinion. In the case under discussion, we observed that at the beginning of the canning season, after, perhaps, a spell of rather dull times, we would come down town in the morning and discover that the canneries were in operation. This was not announced by whistles or word of mouth or by the press. We would smell it! The following reactions were noted (of course there were exceptions): Laborers said, "Hurrah;" bankers smiled; hotel keepers swore—some of them in several languages; the Salvation Army thanked God; the merchants said, "Not so bad;" editors wrote scathing editorials; retired business and professional men sought opportunities to address the service clubs; tourists said, "Let's go;" enforcement officers wore a "what next" look similar to that on the faces of people during an earthquake. It appears generally that the enforcement of law seems to bear a certain indefinite relation to the center of gravity of public opinion.

Eventually, however, the cannery operators themselves felt the call of conscience (even a pirate has to have a conscience to be half a hero) and suggested that, if a means of destroying these odors was found, they would gladly abide by the findings. This suggestion was hailed with delight and a courier was at once despatched to the great city in search of a prophet to lead us out of the wilderness. Such a one was readily found. The city is a great place for prophets. (A prophet is one whom we call from a foreign land to confirm our suspicions.) This prophet wisely declined to commit himself until he had been on the ground some time and indulged in many conferences with the natives. Along about Christmas time, 1927, however, he did proclaim the cause of a very great measure of our grief to come from burning fish meal in the rotary driers. Many other proclamations and words of wisdom were uttered by this prophet. It required an-

other two years for all hands to be convinced of the genuineness of his findings, so in the latter part of 1929 the council did again ordain: first, to create the office of cannery inspector; and, later, to require thermostatic control of all fish meal drying apparatus, together with a recording thermograph instrument so that the inspector might observe the time when burning temperatures occurred in the driers. This was done to guard us at times when the inspector might have a cold.

Two more years rolled around and at the close of last season the council again ordained, making it mandatory for those who engage in the business of running fertilizer plants to obtain a permit so to do from the health officer. The application for permit must describe the apparatus to be used and the means for odor control used in connection therewith. The permit is withheld by the health officer unless satisfactory means of such control is installed. The permit is revocable in case the apparatus does not function satisfactorily. The operator who proceeds without a permit violates the ordinance. The finest feature of this ordinance lies in its administration; to wit, the county health officer is made the enforcement officer. If anything goes wrong, we can still pin it on the other fellow! We don't want our local health officer to become disliked.

Summing up our attainments over the thirty years of "trial and error," we find that both the operators and the public recognize the economic impossibility of operating fish canneries which will not carry at least a fishy odor in and about them. But it is further agreed that it is unnecessary to maintain dryers that load the atmosphere with nauseous gasses. The operators admit that something can be done and are willing to cooperate, and the patient public now demands the abatement of this unnecessary and costly nuisance. Canneries contribute materially to our economic welfare, but we cannot afford to be driven from our homes or suffer the embarrassment of having our guests asphyxiated.

Now, let's view the situation "as is" and see what's being done, keeping in mind the present economic possibility of odor elimination, which does not include local odors arising from frying and drying of fish to be canned, odor of decayed fish, steam from presses, odor of products and odor of fresh fish. These, as a matter of pride on the part of the operators, will be kept down by keeping their canneries clean.

Odorless drying equipment has been installed at one cannery by the installation of steam jacketed batch dryers. These dryers consist of horizontal cylinders with a central longitudinal shaft for operating paddles which lift and stir the meal. The steam jacket heats the meal and evaporates the contained moisture, which is drawn off through a condenser under about two inches of vacuum. No nuisance is created by this method because there is no burning or scorching of meal.

The other so-called odorless process is what is known as the Peebles

process, which involves the use of superheated steam at about six hundred degrees Fahrenheit driven through a rotary dryer. The water-laden vapor discharged at the outlet end of the dryer is passed through a condenser which removes the water absorbed from the meal. It then passes through the heater, where it is boosted again to six hundred degrees Fahrenheit, and again passes on its way through the dryer. Very little, if any, nuisance arises from this plant, except, perhaps, the small amount of vapor arising from the condenser products, which may be destroyed by the introduction of chlorine into the steam. Here again we have no great chance of scorching the meal.

This leaves the problem of the direct or semi-direct fired rotary dryer, in which the products of combustion of a furnace pass through and come into direct contact with the meal. In defense of this mechanism it is claimed that if all conditions are right no bad odors result, but so many elements enter to upset the perfect balance required—such as interruption of power, mechanical troubles and breakdown, burner troubles, overloading and irregular feeding due to untrained help, irregular press operation, soft fish, etc., that perfection is almost never attained.

Instead of allowing the gases from these dryers to burden our atmosphere by way of stacks, we pass them through condensers where the scrubbing process eliminates perhaps ninety per cent of the odor. This is quite an improvement, as it leaves more air for breathing purposes about town. The introduction of chlorine gas along the line between the preliminary and final condensation is suggested as a further step toward perfection. That is to say, in case chlorine gas is used, it is found to function very much better as a deodorizer if admitted with a water bearing vapor instead of a completely dehydrated vapor, for the reason that the chlorine and water form hydrochloric acid and nascent oxygen, and nascent oxygen has a very ardent affinity for the nauseous nitrogen compounds. Therefore, the process of oxidation is promoted by introducing chlorine between the preliminary and final dehydration. This chlorination process may follow in time as our population becomes more discriminating.

Ozone has been, and is now, I think, used in one plant as a deodorizer in connection with the scrubber, but I feel inclined to believe that ozone may be classed as a veiler and not a destroyer of odors. Oil of cinnamon would be cheaper and better.

One other manner of producing noxious gases is that of blowing oil. This process is an oxidizing process for making a quick drying oil for the paint trade, and is accomplished by blowing air through fish oil which has been heated to about 250 degrees Fahrenheit. The gas which is evolved from the oil-blowing process will quickly kill any pedigreed dog; therefore, vapors from oil blowing kettles should always be burned in a furnace and never be allowed to escape in a civilized community.

Symposium on Stream Pollution

Stream Pollution as It Affects Water Purification*

BY PROFESSOR E. M. CHAMOT
Cornell University, Ithaca, New York

Present-day engineering and chemistry have amply demonstrated that we can easily and economically eliminate waterborne diseases and remove bad odors and tastes. It is a relatively simple matter to deliver to consumers a clear water, substantially free from color, odor and bacteria; it is also a practicable project to soften waters on a large scale. It is merely a question of paying the bills. But this is always money well invested.

It appears to be well established that the use of a polluted water for general household purposes reduces the resistance to disease of those compelled to use it, for Hazen and others have shown that for every death from waterborne diseases prevented by the introduction of purification methods two other lives are saved. This raises the question—What is there in a polluted water that tends to lower the resistance to disease? We cannot say.

It is safe, however, to take the ground that the removal of turbidity and subsequent disinfection is by no means all of our problem. Can we wholly ignore consideration of substances in solution which pass through our filters? Are we justified in forcing consumers to drink water tasting so strongly of chlorine as to be decidedly distasteful? Granted that the consumer may be thus saved from something worse, nevertheless we do not know whether these repeated small doses of chlorine are harmless. There is little justification, save in times of a threatened epidemic, for a residual chlorine test being constantly obtainable at the tap of the consumer. It is neither wise nor good management. Yet with a badly polluted raw water safety dictates an excess of chlorine over the chlorine demand of the water.

We are entering an epoch in which the profound influence upon health and disease of very small doses of compounds is beginning to be fully appreciated. This is no new discovery; it has been long known and has been applied in homeopathy for many years in the treatment of disease. But the possible insidious effects upon the healthy individual of continual small doses of inorganic and organic compounds is only now being properly appraised.

What have we in the effluents of our sewage disposal plants that may be deleterious to health when such effluents are discharged into a stream used as a source of water supply? We do not know. Our present methods of water purification cannot remove the water soluble compounds. Does chlorination render them inert or make them even more objectionable?

* *Presented before the Fall Meeting of the New York State Sewage Works Association, Ithaca, N. Y., Oct. 15, 1931.*

Some of us have long believed that there probably are compounds in such waters which may have a marked physiological action even when present only in minute quantities. However, this is mere speculation, but is a problem upon which much research must be done.

I raise this question seriously and bring it to your attention for I think you will all agree that the so-called "domestic sewage" of today is generally a much more heterogeneous product than it was two decades ago. I shall return to this matter promptly, but for a few minutes I wish to direct your attention to what takes place when sewage is discharged into a stream and what provision nature has made to dispose of objectionable material (that is, material deleterious to aquatic life). Let me state at once that when man throws upon Mother Nature the task of disposing at once of a great quantity of foul wastes, she does not and cannot do it.

The agencies which she can call upon to undertake the task are—sedimentation, action of living organisms, dilution, sunlight, oxidation and chemical reactions. I wish to appraise these possible agencies at work in the natural or self-purification of streams. You may not agree with my appraisal, yet it is based upon well-established data.

If the stream is slow moving and has a moderate amount of electrolytes in solution, a considerable quantity of colloidal matter may be agglutinated and sedimentation takes place. Certainly in all but very swiftly moving streams there is considerable precipitation. The most important of all agencies is the action of living organisms. A discussion of this I leave to my colleagues who follow me in this symposium.

Next, and the most important and only agency other than sedimentation which works rapidly is dilution. Practically all the published accounts of running water having purified itself can be explained by dilution—the analytical data sustain this view. If the analyses are scrutinized it will be seen that the chlorine (*i. e.*, chlorides) have diminished in almost the same ratios as have the ammonia and the bacteria. The chlorides are indestructible. Hence we have no alternative but to conclude that there has been no true purification—merely a dilution. Comparing analyses made just below the point of pollution and points down stream, we would, of course, say that the water down stream was "purer." This is a most unfortunate way of stating the case. What we really mean is that the hazard of drinking the water or using it in other ways is less as we go down stream.

There are few streams that do not have tributaries and few that do not receive increments of ground waters. Usually these tributaries and ground waters are of better quality than the main stream; hence the dilution.

We know that there is little or no true chemical oxidation in our streams and ponds and that the profound changes in ammonias and nitrogenous matter are brought about through the action of living organisms, biochemical changes which require time and a suitable environment. We

also know that the decrease in the number of bacteria is due to dilution, lack of food or destruction by other organisms.

Just as we can dismiss oxidation as without appreciable effect, save that oxygen is necessary to sustain the life of the organisms instrumental in the purification of polluted waters, so we can dismiss sunlight as of very little direct effect. The germicidal effect of sunlight upon a flowing stream or pond is so slight as to be negligible. But it is, of course, true that sunlight plays a most important rôle in biochemical reactions. Lastly, in all biochemical reactions involved in the self-purification of streams, time is an important factor, and so far as the disposal of sewage colloids is concerned none of our streams are long enough for natural purification to take place to a degree such that we are justified in passing the waters as safe for drinking, unless treated by some artificial purification process.

The discharge into streams of industrial wastes, which interfere with or inhibit biochemical processes, introduces further hazards not only for man but for all aquatic life.

I repeat the statement that the domestic sewage of today differs from that of twenty years ago. What I mean is that more extraneous matters are poured into the sewers. Many chemical preparations are now used in the household that were not used two decades ago. Antiseptics of many sorts are in common use—cleaning powders, alkalies, hypochlorites and a host of compounds of all sorts, and to this motley array of effective and ineffective products we must add the by-products of home brew. Poured into the sewers in a highly concentrated state they may profoundly affect a sewage disposal plant or pass directly in an effluent into a water supply, stream or lake. These compounds in solution are not removable by our water purification plants and where the dilution is not great, present a problem which cannot be ignored.

Water purification plants, as already stated, remove material in suspension. If the system is of the rapid American type using coagulants, little more is accomplished, for the rate of filtration is too great to allow time for the consummation of biochemical processes.

Efficient filtration, *i. e.*, effecting economical and bacterial efficiencies, requires a proper adjustment of the coagulant dosage so as to obtain a floc which will settle rapidly and very completely, so that little of the aluminum hydroxide passes over upon the filter beds. Judicious adjustment insures long filter runs, short wash periods and a minimum of waste. Anything in the raw water which tends to impair the character or rate of settling of the floc lowers the general efficiency of the plant.

The most efficient floc is produced within a quite narrow pH range. Any substance in the water which changes the pH to an extent such as to give rise to the formation of a less effective floc renders it less easy to obtain a water of satisfactory quality.

Our city (Ithaca) has four streams flowing through it. Two of these, Six Mile Creek and Fall Creek, are sources of water supply, the former stream supplying the City of Ithaca, the latter Cornell University. Each supply has an independent purification plant. The two streams are roughly one to two miles apart as they flow through the city, and their watersheds are not many miles apart. Both watersheds are mainly farming land and wood lots. The waters of both streams are polluted. Fall Creek in addition to farm pollution has a number of private sewers discharging into it some 12 miles above the filter plant. Owing to a slight difference in the topography and soil of the catchment area of Six Mile Creek, its waters average a higher turbidity than do the waters of Fall Creek, yet because of the sewage pollution Fall Creek requires two to three times as much coagulant and two to four times as much chlorine to yield an effluent of quality equivalent to that obtained at the Six Mile plant.

This, you will say, is a mere matter of costs, but increased cost is by no means all. The pollution of a relatively small stream is not constant but varies at different times of day and on different days. The adjustment of coagulant and of chlorine must be such as to take care of sudden changes—changes which are not discernible to the eye and which may or may not be accompanied by a rise in turbidity. Plants dealing with raw waters of this character require far more supervision than plants treating a less polluted water.

Fortunately, clear-wells and distribution reservoirs of adequate capacity can minimize the hazard, for dilution here also comes into play and if an operator makes a slip now and then it is not discoverable in analyses unless the mistake in judgment covers an hour or more, for the dilution is too great.

Excessive dilution thus appears to be one of our most important safeguards in the disposal of sewage and industrial wastes and in the safeguarding of our municipalities.

Stream Pollution as It Affects Fish Life*

BY EMMELINE MOORE

Investigator in Fish Culture, New York State Conservation Department, Ithaca, New York

One may conveniently divide polluting materials into two classes: first, inorganic substances, such as chemicals, gas wastes, lye, etc., which may kill not only the fish but also all the life of the stream by direct poisoning; second, organic wastes such as sewage, milk plant, canning factory

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and similar wastes which by decomposition absorb the dissolved oxygen in the water, often adding, however, by-products of decomposition in sufficient quantities to be toxic.

The effect upon fish of these various wastes forms the background of testimony of a great number of cases against offenders in this state who have violated the Conservation Law, Section 247, Article 2, which reads:

> "No dyestuffs, coal tar, refuse from a gas house, cheese factory, creamery, condensery or canning factory, sawdust, shavings, tan-bark, lime or other deleterious or poisonous substance shall be thrown or allowed to run into any waters, either private or public in quantities injurious to fish life inhabiting the same, or injurious to the propagation of fish therein."

Offenders generally, if the issue is clear cut, are anxious to settle by stipulation rather than to be hailed into court. Relatively few cases, in fact, involving the actual killing of fish are brought into court, the offenders preferring to settle by stipulation rather than run the risk of unfavorable court decision with heavy penalties which the law prescribes.

Gas Wastes

Among the polluting materials of inorganic wastes, experiment has shown that gas wastes are among the most dangerous, not only because of the great toxicity of these wastes but because of the failure of the fish to recognize and avoid the danger zone, with the result that they stay in it and die there (Shelford,[1] 1917). Gas wastes vary in type and in toxicity. Experiment has shown (Marsh,[2] 1907) that perch are killed when subjected to floating tar wastes in the proportion of 1 to 100,000 for a period of five days. Effluents from gas works when allowed to run into streams are conspicuous enough to those who observe carefully. All particles—sand, gravel, rubble, etc.—in the stream bed become coated with the so-called top waste. When such conditions occur, the concentration of this waste in the stream is highly toxic. No fish or other biological unit in its food chain can live in it. Other tarry wastes of greater specific gravity than water spread gradually over the bottom like asphaltum pavement. This waste, while less toxic than the top waste, becomes virtually indestructible and the stream bed wholly unfit for fish life if the stream is a shallow one. Furthermore, waste waters from gas works in the concentration of 0.5 per cent have been known to kill trout in 10 to 15 minutes (Knight,[3] 1901).

Freezing Mixtures

Not infrequently there occurs a sudden, heavy mortality of fish in streams situated below an ice plant in which the ammonia freezing mixture is used. In such cases the trouble is traceable usually to a breakdown in the plant and the accidental loss of the chemicals. This effluent is highly

destructive. The fish which succumb are caught unawares in pools where they normally congregate. They may be killed in a series of pools down stream, for the reason that ammonia gas when in solution under pressure weakens gradually and may require not only some time for dissipation but a considerable dilution to render it non-toxic. As little as 5.5 to 7 p. p. m. of ammonium carbonate will kill fish; 10 p. p. m. of ammonium hydrate will kill fish, such as, shiners, carp and suckers;[4] trout are even more sensitive. Death occurs suddenly and the fish show no lesions.

Glue and Tannery Wastes

Effluents from glue factories, tanneries and leatherette concerns contain large amounts of caustic lime. The retaining basins which are usually adjuncts of these concerns may effect partial clarification. In such clarification basins the caustic alkalinity precipitates protein and acid wastes tend to neutralize the excess lime. However, caustic lime is always used in excess in these processes and passes through the settling basins to the stream below, completely annihilating fish life for appreciable distances. In cases of heavy pollution the zone of lime pollution has been known to extend four to six miles, dependent upon the character of the stream bed and the flow of water. Caustic lime should never reach a fishing stream since it takes so little to kill fish, only 18 p. p. m. (Marsh,[2] 1907).

Laundry and Wash Wastes

Laundry and wash wastes, in which strong lye and water softening chemicals occur, raise enormously the alkalinity of the stream, producing unfavorable conditions or, as in known cases, instant death. During the summer of 1931 there occurred a case of this sort in which the strong washing powders used by a bottling works burned the vegetation brown and killed all animal life, including many fine trout, for a distance of about two miles.

It is impossible to estimate the results of such a wasteful happening. So far as the fish themselves are concerned, in the courts each fish is valued at $10.00. In dealing with fish life, however, everything is included in the stream and cannot be expressed in terms of money. Besides the fishes are the other vertebrates; worms, insects and other invertebrates; plants ranging from the larger aquatics to minute forms; and last, not least, but greatest in the economy of the stream, the myriads of microscopic life comprising both plants and animals and border-line forms.

It is well known that laundry wastes interfere with and seriously handicap the proper operation of the Imhoff tank.

Silt Pollution

Perhaps one of the less well-known types of inorganic pollution is that caused by silt from gravel-washing plants. Such plants frequently make

inadequate or no provision for the disposal of silt and the flow of mud from the washer. It is turned into the nearest convenient stream. The fine sediment soon covers the stream bed with a soft, shifting ooze that completely sterilizes it for a considerable stretch and may seriously roil the water for miles below. As paradoxical as it may seem, this is a type of pollution not named in the pollution law among the "Thou shalt nots," yet it represents the only successful case carried through the New York State Supreme court within the last few years, with a verdict of guilty and the imposition of a maximum fine. In a badly silted stretch, all fish life and the inter-related forms become obliterated. On several occasions I have observed the reaction of fish to the roil. Schools of minnows advance down a clean water tributary to the roily stream, poke their noses or heads into it and suddenly retreat, there being apparently an antipathy to the excessive turbidity. This is repeated many times. Presumably the pressure of population in the smaller tributary accounts for the successive advances toward the larger stream in search of food, or it might be due to their natural curiosity.

Paper Mill Wastes

Paper mill wastes discharged into a stream without adequate dilution or treatment inevitably harm fish life. In New York State two processes for converting wood into paper pulp are in use—the soda process and the sulphite process, though the latter is the more common. In both there is a probability of well-marked chemical pollution as well as mechanical. In the soda process the extractives are less deleterious chemically on account of the greater ease with which they can be treated. There is, however, much loss of wood fiber, which forms practically an indestructible blanketlike covering of pulp, limiting the spawning, rearing and feeding areas of the fish. On occasion there is considerable interference with the movement of fish over such areas on account of suspended pasty pulp deposits which attach to the gills and may cause death through suffocation.

In the sulphite process the waste liquors hold in solution over 50 per cent of the dry weight of wood. This means that for every ton of sulphite pulp produced there is a wastage of a ton or over of wood constituents, which find easy disposal into fishing waters.

The chemical extractives by the sulphite process may be "classified[5] as sugar, alcohol, aldehyde, cymene, acetic and formic acids and furfural," in addition to a small amount of free and loosely combined sulphur dioxide. These materials together with the pulp wash water constitute the sulphite waste liquor—wastes which are detrimental principally on account of their high oxygen demand.

By experiment it has been found that sulphite liquor (density, 1.028 at 11° C.) in a dilution of 1 to 50 without aeration killed 9 out of 12 brook

trout fry in 48 hours; with aeration a 1 to 100 dilution failed to kill bass in 17 days (Marsh,[2] 1907).

The constituents of the sulphite wastes in the main are the non-cellulosic, non-fibrous parts of wood which form valuable by-products, such as tanning extracts, briquetting materials, sulphite alcohol, glue, etc., but recovery processes are not in use because either the wastes produced during distillation are objectionable or the demand for the by-products is small.

These illustrations of the effects of trade wastes are sufficient to call attention to the types of substances which may kill fish by direct poisoning, by suffocation or by rendering the stream barren of food. A report by the New York Conservation Department entitled "Limits of Tolerance of Fish to Trade Wastes," 1921, represents a compilation resulting from an extensive search of available literature on the subject. This report, exhausted for distribution at present, is available in libraries containing the Eleventh Annual Report of the Conservation Department, 1921.

Sanitary Wastes

The polluting waste of greatest volume is sanitary sewage. At the present time relatively few municipalities treat their sewage because of the expense and lack of direct benefit to them. They cannot be compelled to do so unless conditions are created which are a grave menace to public health. Perhaps because we are rooted in a bad tradition proper disposal methods are not yet regarded in the light of a public utility. Yet man and fish need adequate pollution laws.

It has been observed repeatedly that certain species of fish will swim to sewer outlets and feed there without apparent harm. Bullheads, suckers, chubs, carp and others do so. This is explainable because the organic material may still be fresh and in this condition is frequently relished by fish in situations within restricted limits, as between dams or other barriers, where the normal food organisms are limited and where decomposition processes producing septic conditions have not yet been reached. Farther downstream where septic conditions are likely to prevail as, for example, in ponded areas where the current slows up or in holes and depressions in the stream bed and where active decomposition is going on, fish are not present. They respond negatively by retreating to more tolerable areas. Thus the septic zone becomes a barrier to migrating fish either up or downstream. It is difficult to estimate in terms of fish life the effects of such a barrier, though in this type of waste as in some others of organic origin, the "principle of self-purification of rivers" operates to repair some of the damage by mineralization of the wastes. However, with improving concepts of decency, too much organic filth goes into the rivers and too little repair of the damage is obvious through increased fertilization of the stream.

Miscellaneous Organic Wastes

Milk wastes,[6] certain canning[7] and other wastes from food factories may be considered in the same category with sanitary sewage, in that all such wastes must be oxidized in the mineralization process to their original constituents—water, carbon dioxide and minerals. The characteristic plants and animals which play an important part in the process are the protozoa and bacteria, among the microscopic forms; sewage fungi and molds among the non-green plants; and tubifex worms, sewage flies and rat-tail maggots among the animal forms. All are active agents in bringing about the transformation of the waste materials but at great cost of the dissolved oxygen in the water, resulting in a depleted supply for fish life.

When a stream is so heavily polluted as to reach a point favoring the development of a pollution flora and fauna, as enumerated above, it certainly may be characterized as in a dreadful mess. Gas bubbles, due to putrefactive processes brought about by bacteria, escape in quick succession to the surface; black sludge deposits and foul odors arise; slimy fungi cover the stones and other surfaces in the stream bed; worms and maggots burrow in the wallow. Among all indicators of pollution, the rat-tail maggot is one of the most useful as a test organism. It is provided with an air tube like a periscope and by means of this can get air at the surface while burrowing about in its preferred habitat of foul wastes devoid of oxygen.

When a manufacturer of milk products, or canned products, has been evading the law, the presence of rat-tail maggots in the stream below him is as good as a conviction. There is no comeback, for no fish or other biological unit in its food chain can live without oxygen. That is a self-evident truth, and becomes *a priori* evidence against him. It is certainly "injurious to fish life" if there is no oxygen in the water.

I pass on to a final word. The dominant note that runs through any consideration of a subject such as this is the urgent need for a more enlightened public opinion. It is our opportunity to break away from the old tradition and to help create a better public sentiment. We must approach the problem with the scientific attitude, with an appreciation and understanding of our highly industrialized modern conditions, a familiarity with all the factors which have contributed to the present deplorable state of our streams, and finally a sensitiveness to the right use of our resources for the future.

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The Biology of Stream Pollution*

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The disposal of sewage and other wastes into fresh water streams and lakes is common practice in this country. All of these wastes, whether organic or inorganic, whether poisonous or non-poisonous, have some effect upon fish and other fresh water organisms which inhabit such waters. Organic wastes, such as milk wastes, domestic sewage, cannery wastes and others, when introduced into streams in small quantities, may actually benefit the streams in so far as fish life is concerned. However, just as a gardener may smother his plants by applying too much fertilizer to the soil, so the fresh water organisms may be destroyed by the presence of too much organic waste material, whether this be milk, sewage or some other form of organic matter.

The writer has found that in many instances where streams were being polluted by milk wastes, domestic sewage and other forms of organic matter, the conditions of the streams were actually improved in so far as fish and other fresh water organisms were concerned. Non-poisonous organic wastes contain much material which is of food value to the smaller plants and animals, such as algae, fungi, protozoa, snails, water fleas, insects, etc. These organisms in turn become fish food and since the successful production of fish depends in a great measure upon the relative abundance of available food, a certain amount of organic material is a vital necessity to a fish-producing stream.

Among the waste products which so often find their way into fresh water streams we find many which are directly poisonous to the normal inhabitants of the waters and these wastes, even in small quantities, can be of no real value to the stream and, in most instances, they cause a great

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deal of harm. Cyanides, acids, wood distillery wastes, oils, pulp wastes and the like are directly harmful to fish life as well as to the organisms which form the normal food of fish.

Our laws regarding stream pollution are rather definite in defining what wastes may not be discharged into a stream. The New York State law says: "No dyestuffs, coal tar, refuse from a gas house, cheese factory, creamery, condensing or canning factory, sawdust, shavings, tanbark, lime or other deleterious or poisonous substances shall be thrown or be allowed to run into any waters, either private or public, in quantities injurious to fish life inhabitating the same or injurious to the propogation of fish therein." There is no question about the definiteness of the law, but how shall we determine whether a substance in varying dilutions is or is not deleterious to fish life? Certainly no one would say that a teaspoonful of sulphuric acid thrown into the Hudson River would be very harmful to fish or any other life in the river, even though sulphuric acid as such is distinctly harmful to living organisms. Much less would one dare to pronounce it a case of harmful pollution, should some one dump a pail full of milk into the Susquehanna River. Should, however, a large wood alcohol distillery discharge all of its wastes into a small trout stream all fish and other fresh water organisms would probably be killed for many miles. Similarly should a milk plant or domestic sewage plant discharge a large volume of concentrated waste into a small stream all the fish and other fresh water life might be completely wiped out.

On the whole the question of pollution is largely one of *dilution*. No water in its natural conditions is ever pure. In fact, pure water is sterile and sterile water does not exist in nature and furthermore it is not desirable. Poisonous wastes must not be present in fresh water in sufficient quantities to affect the normal life of the stream and naturally the best safeguard is to keep such wastes out of the streams altogether. This is not always possible nor practicable. Factories in cities have no easier means of getting rid of their wastes than to empty them into the city sewer, and the sewage, usually after treatment, finally finds its way into a lake or stream. Fortunate is the city or factory which is located on a body of water large enough to absorb such wastes without materially affecting the waters or polluting them sufficiently to cause any harm.

Most organic wastes, as has been pointed out, are not poisonous to living organisms, but when present in large quantities they often deplete the waters of the normal plant and animal inhabitants. Fish and other fresh water organisms depend for their respiratory functions upon the oxygen which is dissolved in the water and the moment the oxygen supply is not available the organisms suffocate. Nearly all organic wastes have one characteristic in common and that is that they are subject to putrefaction. In this putrefaction process the organic materials use up the oxygen

more rapidly than the water is able to absorb it from the air. Thus they rob the fish and other organisms of their oxygen supply and as a result the water no longer remains habitable to fish and other forms of life. It is of utmost importance then that sewage and other organic wastes shall not be added to fresh water in sufficient quantities to reduce materially the oxygen content of the water.

In the case of organic wastes it is not only a question of dilution but to a very large degree also a question of the type of stream into which such wastes are discharged. A quiet body of water, or, a slowly flowing stream can "absorb" much less organic material than a swiftly flowing stream which is continuously stirred and aerated as it speeds along over rocks, riffles and falls. It thus becomes apparent that the problem of evaluating a stream or determining its state of pollution is not an easy one. Nearly every type of waste reacts differently upon fish and other forms of life and every stream presents its own peculiar problem.

The methods of evaluating a stream are in the main the following: (1) superficial observation of the condition of the stream; (2) chemical analysis of the water; (3) minnow tests and (4) examination of the stream for the presence or absence of biological indicators.

The first method, that of superficial examination of the condition of the stream, is subject to gross error. Discoloration of the water by a harmless substance may lead one to believe that the water is badly polluted, while water which looks clear or clean to the eye may actually be contaminated with a colorless poison deadly to fish life.

Chemical examination has been resorted to in many instances. Now whereas chemical analysis of the water may give us a clear index regarding the oxygen content and the presence or absence of any deleterious substances, it tells us only what the condition of the water is at the *moment of examination*. It gives us no clue as to the amounts of wastes which were discharged a day or a month before such examination, for those wastes have long since been carried far down stream. Nor does a chemical examination tell us whether the stream will be fit, in the near future, for the production of fish life. This is not an argument against the use of chemical analyses for determining conditions of pollution. It merely points out the limitations of such a method.

Minnow tests have been used extensively to determine questions of pollution. This method is based upon the assumption that when live minnows are placed in a stream below the point of entry of waste materials their reaction to the polluting substances will serve as an index of pollution. If minnows are killed in the course of an hour or more, the stream is said to be polluted to the extent of being harmful to fish life. If, however, the minnows are still alive after a period of three or more hours the waters are generally pronounced "clean." It is obvious, of course, that such minnow

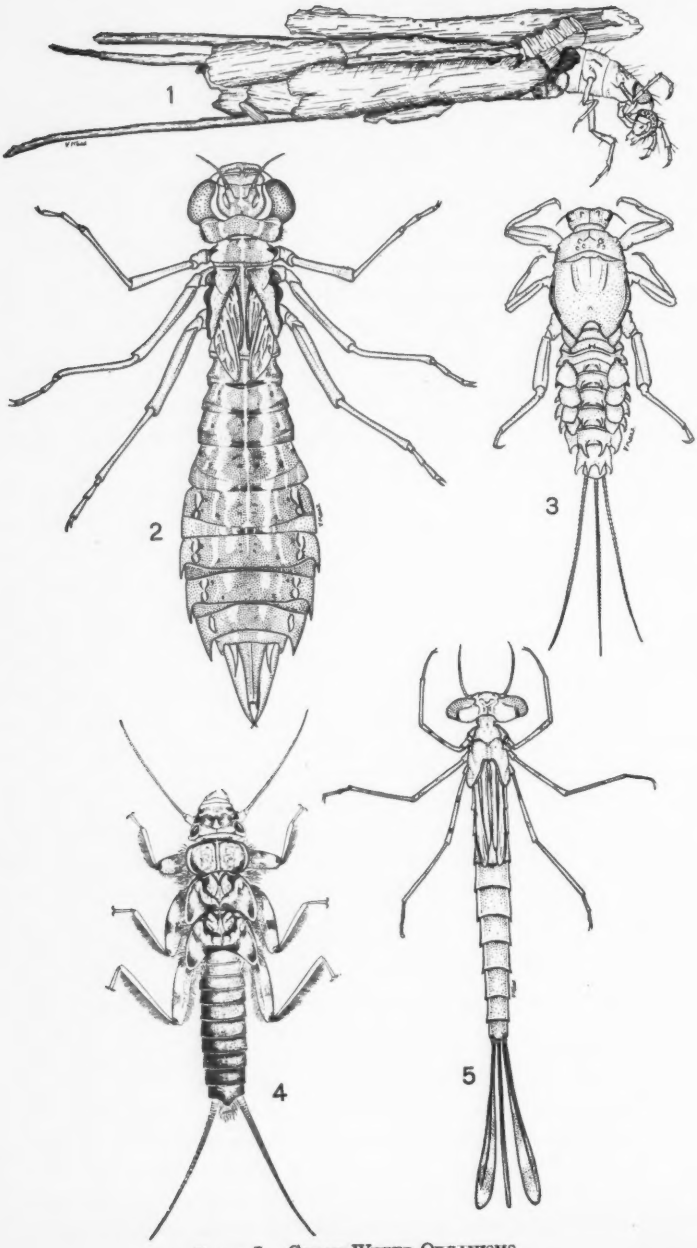

PLATE I. CLEAN WATER ORGANISMS.

DESCRIPTION OF PLATE I.

FIG. 1.—Caddisworm. These worms live in portable cases which they build. They are found only in unpolluted waters. When the worms grow up they transform into moth-like Caddisflies.

FIG. 2.—Dragonfly Nymph. These nymphs feed upon other insects in the water. After living one or two years in the water they change into graceful dragonflies or "devil's darning needles."

FIG. 3.—Mayfly Nymph. These nymphs live upon vegetation and after a long stay in the water they change into delicate mayflies which live only a day or so on the wing.

FIG. 4.—Stonefly Nymph. These nymphs commonly occur under stones in swift water. The adults are poor fliers and mostly remain near the water.

FIG. 5.—Damselfly Nymph. These nymphs are found mostly in quiet fresh water. They transform into graceful damselflies which are often seen hovering over the water.

tests are, as in the case of chemical analysis, indicative only of the condition of the water at the time of the test and they tell us nothing of the condition of the stream at any time previous to such a test. In fact, even in instances where minnows have remained alive over a period of eight hours or more, it would be unsafe to say that no deleterious substances were being discharged into the water. Fish and other organisms respond very slowly to some poisons and whereas eight or twenty hours might show no appreciable effects, the continuous presence of such wastes might ultimately not only weaken the fish but actually kill them.

The most reliable method of evaluating a stream is through a study of the plants and animals which inhabit it. Any stream which contains fish or which is capable of maintaining fish life must also maintain a large population of other living organisms, both plants and animals. The normal food of trout and other fish consists largely of insect larvae and other small forms of animal life. These food animals are for the most part herbivorous, or plant feeders and the algae and other forms of aquatic plants make up the pasture for the animals upon which the fish, in turn, feed. The presence or absence then of these fresh water plants and animals in a polluted stream not only gives us an indication of the condition of the stream at the time of examination, but gives us positive information whether the stream has been polluted weeks or even months before the time of study.

The presence in a stream of such living forms of insects as are shown in Plate I (Caddisworm, Dragonfly nymph, Mayfly nymph, Damselfly nymph and Stonefly nymph) is a sure indication that the stream is not being polluted to the extent of being injurious to fish life and furthermore their presence clearly shows that the stream has not been polluted for weeks or months previous to the time of examination. Most of these insects have a long life cycle, that is to say, they remain in the nymphal or larval stage for a year or more. On the whole these insects, which constitute a large proportion of the food on which the fish live, do not migrate very far in a stream. Hence, once a stream bed has been depleted

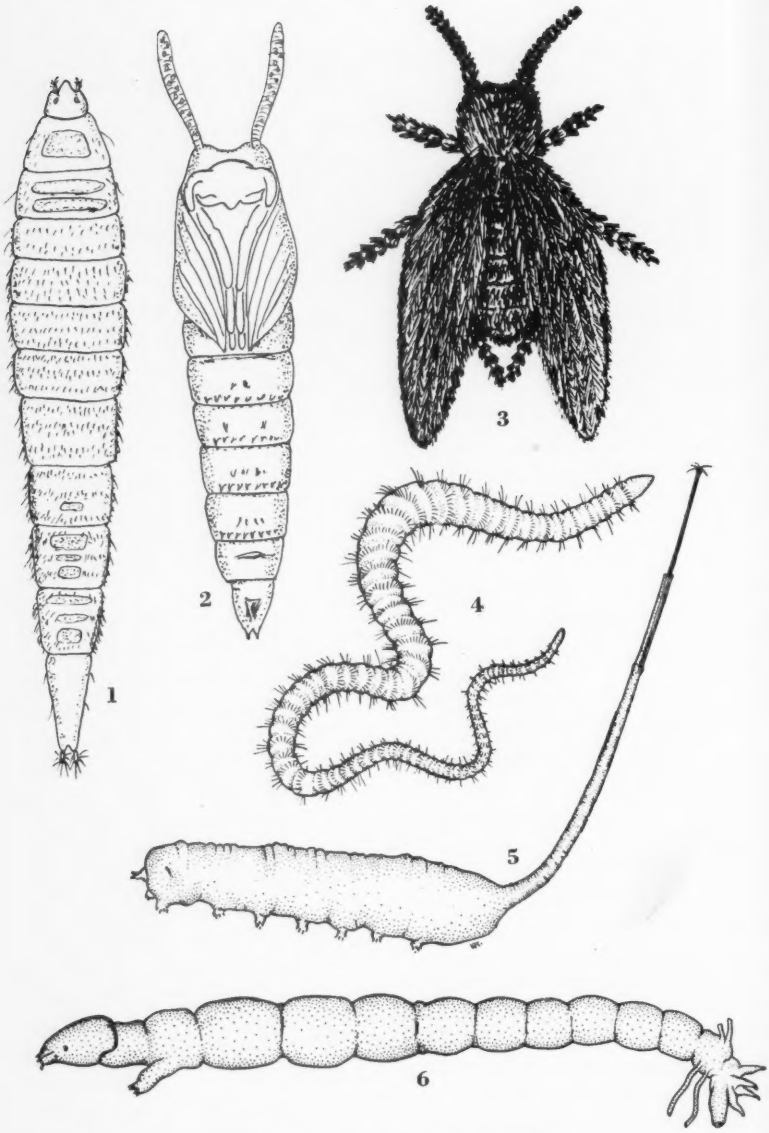

PLATE II. POLLUTED WATER ORGANISMS.

DESCRIPTION OF PLATE II.

FIG. 1.—Larva of Sewage Fly (*Psychoda*).

FIG. 2.—Pupa of Sewage Fly.

FIG. 3.—Adult of Sewage Fly. (After Headlee.) This fly is very common in sewage filter beds and the little moth-like adults often become a nuisance. The larvae feed upon the organic matter found in sewage.

Fig. 4.—Sewage Worm (*Tubifex*). These reddish worms occur in the bottom soil of polluted waters. The worms have a habit of extending their bodies upward out of the soil and waving to and fro. When disturbed the whole colony quickly withdraws into retreats in the ground.

FIG. 5.—Rat-Tail Maggot (*Eristalis*). This larva has an extensile respiratory tail which it protrudes through the surface film in order to obtain air. When mature the larva transforms into a fly which resembles the honey bee.

FIG. 6.—Bloodworm (*Chironomidae*). The bloodworm lives in water which is not so highly polluted as in the case of the other insects above. These worms transform into small midges which superficially resemble mosquitoes.

of these insects it requires many weeks for new generations to again become established. The writer has found instances where a stream was being badly polluted early in the spring and where practically no polluting substances were discharged into the stream after June 15, and yet a biological examination of this stream in September very clearly told the story of that early pollution. Although the water in the stream was clear and "clean," and although chemical analysis showed the water to be "perfect" and minnow tests proved satisfactory, a biological examination revealed what no other test could have shown, namely, that the entire fresh water fauna and flora had been exterminated and had left the stream as barren to fish life as a burned over meadow would be barren to livestock. The absence of fresh water organisms, however, would have been only an *indication* of what had happened and would not have constituted a *direct proof*. The direct proof was found, however, when an examination of the stream above the point of entry of the wastes revealed the presence of all the normal fresh water form of plant and animal life, and had the stream below been unpolluted the same organisms should also have occurred there. The biological examination, therefore, was the only reliable method of evaluating this stream. It sometimes happens that the greatest concentrations of wastes are discharged into a stream at a time when the stream is at its lowest volume of flow and within a few hours this waste has been carried so far down stream that no method other than a biological examination will reveal a true story of such a happening.

Polluted waters, especially those polluted by organic wastes, also have their particular types of plant and animal inhabitants and the presence of such animals as are shown in Plate II (Sewage fly; Sewage worm; Rat-tail maggot and Bloodworm) and of such plants as *Oscillatoria*, *Sphaerotilus* and *Leptomitus* are indicators which tell us that the water is being polluted

to the extent of harming or killing fish and other fresh water organisms. These pollution forms are able to live in water which is low in oxygen content and they are usually found in streams which are badly polluted by organic wastes.

In addition to the animals shown in Plates I and II, there are many other clean water forms of plant and animal life as well as polluted water forms which serve as biological indicators in evaluating a stream, but it is not within the scope of this paper to go into the discussion of these forms. The forms discussed and illustrated in this paper constitute the more readily observed animals and these serve fairly well in determining whether a stream is being polluted to the extent of being injurious to fish and other forms of fresh water life.

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Editorial

Essen and Birmingham

The Essen-Rellinghausen sewage treatment works is undoubtedly the most interesting plant in Germany, and the Birmingham treatment works holds a similar position in England. For variety of processes, length of service and authoritative results these plants are unexcelled in Germany and England. In addition to the Essen-Rellinghausen plant there are several other plants of great interest near Essen, including Essen-Frohnhausen and Gelsenkirchen. But the treatment works only reflect the skill and experience of the designers and operators, and nowhere can more illustrious names be found in the roster of sewage engineers and chemists than those of Imhoff, Prüss, Bach, Sierp, Fries and Blunk, of Essen, or those of Watson, O'Shaughnessy and Whitehead of Birmingham.

The abstract section of THIS JOURNAL usually includes one or more abstracts of articles by these men, but it happens that this issue is unusually rich in references to their works. There are three abstracts of articles on the Birmingham plant (pages 204, 207 and 211) and four on plants in or near Essen (pages 187, 194, 201 and 203). The article by Franz Fries on the Essen-Rellinghausen plant is of outstanding interest and the discussion of sludge digestion by Messrs. O'Shaughnessy and Whitehead is also of great importance. These are possibly the most important papers on sewage treatment that have been presented in Germany and England during 1931, and for that reason they have been abstracted in detail. The abstracts warrant careful study by American readers and in many cases the original articles will be sought for further details.

The Essen-Rellinghausen plant includes almost every type of sewage-treatment process now in use, and presents an unparalleled opportunity for comparison of all sorts of devices on a comparable basis. For example, there are aerated grit chambers and grease skimmers, Imhoff tanks versus separate-digestion tanks, a separate-digestion tank with mechanism versus one without, aeration tanks with diffused air plus paddle wheels versus air diffusion alone, and underdrained sand beds versus shallow lagoons.

Experimental plants and large-scale operation at Birmingham also afford opportunity for comparison of various processes, for example, separate digestion with and without gas collection and heating, mechanical versus diffused-air aeration, sedimentation plus preaeration versus sedimentation alone, and reaeration versus straight aeration. The most

noteworthy development at Birmingham is the fact that the sludge from nearly one million people has been disposed of since 1911 by controlled separate digestion. Mr. O'Shaughnessy has had to contend for 20 years with the largest sewage treatment problem in England, and based on the experience of these twenty years he is able to evaluate the important factors in sludge digestion and to point out the principal objectives. For example he (and Mr. Whitehead) state that "at Birmingham the major factors influencing the course of the digestion of the sludge are found to be the water content, the temperature and the degree of alkalinity (pH value). Recent work has confirmed the importance of all these factors, but many workers, while showing clearly the effect of temperature and reaction, fail to pay sufficient attention to the influence of the water content."

This statement is quite in line with the editorial in THIS JOURNAL for January, 1931, page 127: "The various factors that affect sludge digestion, such as temperature, age, reaction and depth of tank, narrow down to the final consideration, from the standpoint of cost, of the capacity that must be provided to hold the sludge for the digestion period. This capacity is determined by the average moisture content."

It is apparent from operating data of German and American plants in which activated sludge is digested with settled solids, that the sludge contains a large amount of water, which cannot be decreased in short periods of digestion. Results at Chicago and Peoria, Illinois, Salinas, California, and elsewhere indicate that the average moisture content may be 95 per cent or more, and that sludge as drawn may contain 93 to 95 per cent moisture. The desirability of preliminary concentration is obvious. Dr. Imhoff has built a Dorr settling tank at Essen-Rellinghausen with an underlying sludge chamber, in which, as Mr. Fries states, the moisture content is reduced from 97 down to 94 per cent. The sludge drawn from the first digester, after 18 days, contains 92.5 per cent moisture, and from the second digester, after 26 days, 90 per cent. Apparently the preliminary concentration and two-stage digestion have been of appreciable benefit in reducing moisture content. It will be of interest to learn whether the multi-stage digestion process being investigated by Messrs. Warren and Rawn at Los Angeles will produce a more concentrated sludge than has been obtained elsewhere in America.

Dr. Prüss has modified his circulation scheme so that sludge is not recirculated from the bottom of the tank, but from an elevation some distance above the bottom, allowing the sludge to concentrate in the space below the suction line. Daily stirring from bottom to top, as formerly recommended, resulted in the production of a sludge containing 95 per cent or more water. It will be of interest to learn of further efforts at Essen to concentrate raw or digesting sludge.

The Essen-Rellinghausen plant contains so many novel treatment devices that it is difficult to discuss them in order. The aerated grit chambers are new to American sewage works operators and designers, but aerated grease basins have been tested at Los Angeles and elsewhere.

The low air and power consumption at Essen-Rellinghausen by the paddle-wheel plus diffused-air unit (0.065 cu. ft. of air per gallon and 7 H. P. per million gallons) are lower than similar data reported in America, likewise an aeration period of 2.9 hours is shorter than American or English practice. For comparative purposes it would be desirable to have detailed daily results of operation and daily analyses of composite samples over a period of several months or a year.

The final settling tanks used in England and Germany for settling of activated sludge are usually of the vertical-flow type, with no mechanism. This type of tank seems to be universally preferred abroad, although the use of 2 to 1 slopes on the hoppers makes it necessary to use small units and a large number of hoppers. For example, the Essen-Rellinghausen final tanks are 26 ft. square and with one hopper 25 ft. deep, or with four hoppers 20 ft. deep. These small and deep tanks are quite different from the large, shallow, mechanically cleaned tanks used in America, with width or diameter up to 70 or 80 ft. and depths of only 12 to 15 ft.

Other interesting units in the Essen-Rellinghausen plant include: (1) the use of a drum screen, with 1 mm. slots, located between the settling and aeration tanks, said to be of value when the aeration tank influent contains *chironomus* larvae; (2) an iron oxide purification unit for removal of hydrogen sulphide from the gas; (3) an incinerator for burning coarse screenings; (4) the dilution of returned sludge with fresh water; and (5) last, not least, an annual cost of operation, not including interest and depreciation, of 28 cents per capita, much lower than the cost of complete treatment in the United States.

The Essen-Frohnhausen plant of the Emscher District is discussed by Dr. Husmann in the abstract on page 194. This plant includes in its operating schedule daily circulation of sludge according to the proposal of Dr. Prüss. Dr. Husmann claims that circulation does not increase appreciably the amount of carbon dioxide in the gas, that the sludge settles quite well a few hours after circulation ceases and that if difficulties have arisen in circulation of sludge in the Essen-Rellinghausen plant, they must have been due either to the presence of activated sludge or to too prolonged circulation.

Apparently the geographical propinquity of the Emscher and Ruhr boards is not reflected by a harmonious agreement on technical matters.

In concluding this rambling discussion of recent developments at Essen and Birmingham, it is only fitting to mention the high regard held in America for those pioneers in the development of sewage treatment

in Europe, namely, Dr. Imhoff, Dr. Bach, Mr. Watson and Mr. O'Shaughnessy, as well as for the younger men on the staff of the Ruhr, Emscher and Birmingham boards. They have added notable contributions to the advancement of the science of sewage treatment, and we hope for future contributions as prolific as those in the past.

Proceedings of Local Associations

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Representatives, Board of Control: Abel Wolman, Baltimore, Md.; F. H. Dryden, Salisbury, Md.

Michigan Sewage Works Association

President: C. P. McGrath, Mt. Clemens.
Vice-President: R. Anderson, Muskegon Heights.
Secretary-Treasurer: W. F. Shephard, Lansing.
Directors: Fred Dorr, Royal Oak; James R. Rumsey, Grand Rapids; Harry E. Johnson, Flint.
Representatives, Board of Control: James R. Rumsey, Grand Rapids; Harry E. Johnson, Flint.

Missouri Water and Sewage Conference

Chairman: E. E. Wolfe, Supt. Filtration Plant, Hannibal.
Vice-Chairman: W. E. Barnes, Supt. Water Works, Liberty.
Secretary-Treasurer: Herbert Bosch, Asst. Public Health Engineer, State Board of Health, Jefferson City.
Executive Committee: A. V. Graf, St. Louis Water Department, St. Louis; L. W. Helmreich, Supt. Capital City Water Company, Jefferson City; A. E. Thain, Water Commissioner, Neosho; John E. Martin, Water Commissioner, King City.
Representatives, Board of Control: W. Scott Johnson, State Board of Health, Jefferson City; Ralph E. Fuhrman, Supt. Sewage Works, Springfield.

New England Sewage Works Association

President: Warren J. Scott, Hartford, Conn.
Vice-President: Roy S. Lanphear, Worcester, Mass.
Secretary-Treasurer: F. W. Gilcreas, Boston, Mass.
Representatives, Board of Control: Stuart E. Coburn, Boston, Mass.; Julius W. Bugbee, Providence, R. I.

New Jersey Sewage Conference

Chairman: Willem Rudolfs, New Brunswick.
Vice-Chairman: John R. Downes, Bound Brook.
Secretary: Richard C. Smith, Glen Ridge.
Representatives, Board of Control: Willem Rudolfs, New Brunswick; Richard C. Smith, Glen Ridge.

New York State Sewage Works Association

President: John F. Skinner, Rochester.
Vice-President: Prof. Earle B. Phelps, New York City.
Secretary-Treasurer: A. S. Bedell, Albany.
Executive Committee: Earl Devendorff, 1932, Albany; Wellington Donaldson, 1933, New York City; W. P. Gyatt, 1934, Syracuse; C. A. Holmquist, 1932, Albany; Carl L. Howell, 1934, Buffalo; Prof. Earle B. Phelps, 1934, New York City; William A. Ryan, 1933, Rochester; John F. Skinner, 1932, Rochester; Prof. Charles L. Walker, 1933, Ithaca.
Representatives, Board of Control: John F. Skinner, 1932, Rochester; Prof. Earle B. Phelps, 1933, New York City.

North Carolina Sewage Works Association

President: William C. Olsen, Raleigh.
Vice-President: J. H. Lampley, Hendersonville.
Secretary-Treasurer: H. G. Baity, Chapel Hill.
Editor: E. G. McConnell, Charlotte.
Representatives, Board of Control: W. M. Piatt, Durham; E. G. McConnell, Charlotte.

Ohio Sewage Conference Group

Chairman: C. D. McGuire, Columbus.
Vice-Chairman: F. G. Browne, Marion.
Secretary-Treasurer: F. W. Jones, Cleveland.
Representatives, Board of Control: C. D. McGuire, Columbus; Floyd G. Browne, Marion.

Oklahoma Water and Sewage Conference

President: Cecil Harrison, Enid.
Vice-President: Ancel Love, Ardmore.
Secretary-Treasurer: H. J. Darcey, Oklahoma City.
Executive Committee: Fred Cowell, Vinita; R. D. Morgan, Pryor; Leon Bennett, Holdenville.
Representatives, Board of Control: C. H. Bullen, Stillwater; H. J. Darcey, Oklahoma City.

Pennsylvania Sewage Works Association

President Emeritus: Elton D. Walker, State College.
President: Lowell W. Monroe, Ellwood City.
First Vice-President: R. O'Donnell, State College.
Second Vice-President: Harry L. Krum, Allentown.
Secretary-Treasurer: L. D. Matter, Wilkes-Barre.
Editor: J. R. Hoffert, Harrisburg.
Representatives, Board of Control: C. A. Emerson, Jr., Philadelphia; H. E. Moses, Harrisburg.

Sewage Division, Texas Section, S. W. W. A.

President: L. A. Grimes, Abilene.
First Vice-President: J. D. Rogers, Port Arthur.
Second Vice-President: Clyde C. Hays, Waco.
Third Vice-President: Chas. M. Crawford, Childress.
Fourth Vice-President: Dr. E. P. Schoch, Austin.
Secretary: V. M. Ehlers, Austin.
Asst. Secretary and Treasurer: E. G. Eggert, Austin.
Editor: Ella G. White, Austin.
Director, Sewage Division: W. S. Mahlie, Fort Worth.
Representatives, Board of Control: Y. M. Ehlers, Austin; W. S. Mahlie, Fort Worth.

Ohio Sewage Works Conference Group Affiliates with Federation

A group of fifty-five chemists and engineers in Ohio has organized the Ohio Sewage Works Conference Group and made application for affiliation with the Federation of Sewage Works Associations. The application was approved at the annual meeting of the Federation, Jan. 22, 1932, in New York City.

The officers of the group are as follows: *Chairman:* C. D. McGuire, 448 Clinton Street, Columbus; *Vice-Chairman:* F. G. Browne, Marion, *Secretary-Treasurer:* F. W. Jones, 1140 Leader Building, Cleveland.

New England Sewage Works Association
Third Fall Meeting

Providence, Rhode Island, October 19, 1931

The Third Fall Meeting of the New England Sewage Works Association was held at Providence, Rhode Island, October 19, 1931. Headquarters for the meeting were at the Sewer Maintenance Building of the Providence Sewer Department. Ninety-four members and guests were registered.

The meeting convened at 10:30 A.M. with President W. J. Scott presiding. The meeting was opened with an address of welcome to the Association by His Honor, Mayor Dunne of Providence. Mr. Frank E. Waterman, Commissioner of Public Works, also spoke to the members, extending the hospitality of the Department of Public Works to the Association.

The first paper of the morning session, entitled "Sewer Maintenance," was presented by Mr. John H. Brooks, Jr., of Worcester, Massachusetts. In the absence of Mr. Brooks, his paper was read by Mr. Willis E. Cary of Worcester. This paper was discussed by Mr. W. E. Saunders of Providence and several other members.

The second paper, presented by Mr. E. S. Chase of Boston, was entitled, "Sand Filtration." This paper was discussed by Mr. H. E. Holmes, Mr. H. P. Eddy of Boston and several others.

As the last paper of the morning session, Mr. J. W. Bugbee described the methods of sewage disposal used in Providence, outlining previous methods and changes now being made.

Following the discussion of the papers, a brief business session was held. It was voted that the Association allow the Secretary-Treasurer the sum of twenty-five (25) dollars per annum to cover expenses in attending the meeting, the same to be paid at the time of the Annual Meeting each year.

President Scott announced that the Executive Committee had suggested that the Annual Meeting for 1932 be held in Boston. It was voted that the Annual Meeting for 1932 be held in Boston.

The Secretary reported an increase in membership to one hundred and fifteen and also reported a balance of $143.92 in the treasury.

Following the morning session a buffet luncheon was served in an adjoining room in the Sewer Maintenance Building.

At 2:00 P.M. the members were taken on a tour of inspection of the Sewer Maintenance Building, the yard, pumping station and the disposal works. As the disposal works were undergoing reconstruction, including changes in methods of treatment, the inspection was most interesting. An opportunity was afforded the members to study the details of design of several units which were under construction.

In addition to the disposal plant, the Association was invited to inspect the plant of the Field's Point Manufacturing Co., adjacent to the disposal Plant, to observe the manufacture of liquid chlorine.

Following the inspection trips, the meeting adjourned to the Edgewood Yacht Club for dinner and the evening meeting.

Following the dinner, Professor Frederick P. Gorham of Brown University addressed the meeting, speaking on the subject of shell fish and the relation of sewage and sewage disposal to shell fish problems.

During the evening a Round Table Discussion on the following topics was held: 1. "Operating Difficulties with Imhoff tanks," introduced by Mr. Van Kleeck of Hartford, Connecticut. 2. "Odor and Fly Nuisance," introduced by Mr. R. S. Lanphear, Worcester, Massachusetts.

Messrs. Chase and Ellsworth described their very interesting observations of sewage treatment in Europe during visits which they have recently made to various European countries. Mr. Chase accompanied his talk with moving pictures which he had taken of many of the treatment plants in Europe and United States.

It was voted that the Secretary be instructed to express to the Mayor and Commissioner of Public Works, of Providence, the appreciation of this Association for the hospitality extended by the City.

The meeting adjourned at 9:30 P.M.

F. W. GILCREAS, *Secretary*

Missouri Water and Sewerage Conference

Seventh Annual Meeting

Jefferson City, October 22–23, 1931

The Seventh Annual Meeting of the Missouri Water and Sewerage Conference, held in Jefferson City, October 22 and 23, 1931, provided an unusually attractive program consisting of papers and discussions on subjects of interest to water works and sewage treatment plant superintendents. Eighty-two men registered before the close of the conference.

Papers on sewage treatment were given by G. R. Scott of Black & Veatch, Consulting Engineers, Kansas City; R. E. McDonnell of Burns & McDonnell Engineering Co., Kansas City; Geo. S. Russell of Russell & Axon, Consulting Engineers, St. Louis; and H. C. Delzell of the Portland Cement Association, Chicago, Ill.

For the first time in the history of this organization, an entire afternoon was devoted to informal round table discussion of various problems. The results of this session were very gratifying, and it is probable that more time will be devoted to this phase of the program in future meetings.

Following an inspection trip of the Capital City Water Company's filtration plant on Friday, October 23, the members of the conference were served a luncheon at the plant by the water company. The annual dinner on Friday night was presided over by Dr. James Stewart, State Health Commissioner, as toastmaster. After the banquet the ladies attended a theatre party and the men a smoker. On Saturday a number of the members motored to Bagnell for the purpose of inspecting the hydro-electric project recently completed by the Union Electric Company at that place.

At the business meeting, the following officers were elected for the ensuing year: *Chairman*, E. E. Wolfe, City Chemist, Hannibal; *Vice-Chairman*, W. E. Barnes, Supt. Water Works, Liberty; *Secretary-Treasurer*, Herbert Bosch, Assistant Public Health Engineer, State Board of Health, Jefferson City. *Executive Committee:* A. V. Graf, Chief Chemical Engineer, St. Louis Water Department, St. Louis; L. W. Helmreich, Manager, Capital City Water Co., Jefferson City; John M. Martin, Supt. Water Works, King City; A. E. Thain, Supt. Water Works, Neosho; *Representatives, Board of Control:* W. Scott Johnson, State Board of Health, Jefferson City; Ralph E. Fuhrman, Supt. Sewage Treatment Works, Springfield.

HERBERT BOSCH, *Secretary-Treasurer*

Iowa Sewage Treatment Conference
Thirteenth Annual Conference
and
Iowa Wastes Disposal Association
Fifth Annual Meeting

Ames, Iowa, Nov. 18, 19, 20, 1931

The Thirteenth Iowa Sewage Treatment Conference was held at the Iowa State College, Ames, November 18, 19 and 20, 1931. The Fifth Annual Meeting of the Iowa Wastes Disposal Association was held November 19 in conjunction with the conference. Seventy municipal officials, engineers and sewage treatment plant operators attended in addition to staff members and students of the College.

Of general interest was the section of the program dealing with stream pollution, the necessity for sewage treatment and the difficulties of financing. For operators, particular sessions were devoted to a study of sewage treatment fundamentals and operation practice. Round tables gave the opportunity for discussion of problems and the exchange of experience on sewage works operation.

Subjects presented on the program were as follows:

"Sewage Treatment and the Public," by Lindon J. Murphy, Municipal Engineer, Iowa State College, Ames.

"The Sewage Works Operators' Job," by W. Scott Johnson, Chief Public Health Engineer, Mo. State Bd. of Health, Jefferson City.

"How Boone Has Solved Its Stream Pollution and Sewage Treatment Problem," by Mayor H. H. Canfield, Boone.

"The Effect of Stream Pollution on Public Water Supplies," by Jack J. Hinman, Jr., Chief Water Laboratory Division, State Hygienic Laboratories, Iowa City.

"Why Should Municipalities and Industries Treat Their Sewage Wastes?" by Frank Bachman, Chief Engineer, The Dorr Co., Chicago (read by F. G. Nelson).

"How Can Sewage Treatment be Financed?" by Howard R. Green, H. R. Green Co., Cedar Rapids.

"Sewage Settling Tanks," by Earl L. Waterman, Prof. of Sanitary Engineering, State University of Iowa, Iowa City.

"Bacteria in Sewage Disposal," by Dr. Max Levine, Prof. of Bacteriology, Iowa State College, Ames.

"Hydraulics That a Sewage Plant Operator Should Know," by W. E. Galligan, Asst. Prof. of Sanitary Engineer, Iowa State College, Ames.

"The Chemistry of Sewage Treatment," by Jack J. Hinman, Jr., Chief Water Laboratory Division, State Hygienic Laboratories, Iowa City.

"Financing the Operation of Sewage Works," by C. H. Currie, President Currie Engineering Co., Webster City.

"Keeping Sewage Works Records," by W. Scott Johnson, Chief Engineering Division, Missouri State Board of Health, Jefferson City.

"Sewage Treatment Plant Control," Laboratory Instruction in Charge Wm. R. Mark, Jr., Asst. Engineer, State Dept. of Health, and Benj. A. Whistler, Grad. Asst. in Sanitary Engineering, Iowa State College, Ames.

"Gas Recovery from Sewage Sludge," by F. H. Austin, Currie Engineering Co., Webster City.

"Sewage Filters and Their Operation," by Earle L. Waterman, Prof. of Sanitary Engineering, State University of Iowa, Iowa City.

"Factors Affecting the Efficiency of Filtration," by W. A. Stanley of Pearse, Greeley and Hansen, Chicago, L. P. Ellerbroek of L. G. Everist, Inc., Sioux City, and W. E. Galligan, Asst. Prof. of Sanitary Engineering, Iowa State College, Ames.

The annual banquet and meeting of the Iowa Wastes Disposal Association was held on the evening of November 19. After a program of entertainment and short talks, Dean Anson Marston was introduced for the principal address, "The Development of Sanitary Engineering in Iowa."

A short business session followed, concluding with the election of officers for 1932. They are:

President: Max Levine, Ames; *Vice-President:* Earl L. Waterman, Iowa City; *Directors:* Geo. A. Nelson, Boone, and Lafayette Higgins, Des Moines; *Representatives to the Board of Control,* Federation of Sewage Works Associations: W. E. Galligan, Ames, and Max Levine, Ames.

LINDON J. MURPHY, *Secretary-Treasurer*

New York State Sewage Works Association Fourth Annual Meeting

New York City, Jan. 19, 1932

The Fourth Annual Meeting of the New York State Sewage Works Association was held at the McAlpin Hotel in New York City on January 19, 1932. One hundred and twenty members and guests were registered. At the business meeting Messrs. J. L. Barron (White Plains), A. F. Dappert (Albany), L. I. Luther (Freeport) were elected to the Executive Committee in place of Messrs. E. Devendorf, C. A. Holmquist and John F. Skinner, whose terms of office expired. Mr. Skinner, however, continues as advisory member of the Executive Committee for the coming year. Professor E. B. Phelps of New York City was elected President, and Mr. A. F. Dappert of Albany, Vice-President. A. S. Bedell, State Department of Health, Albany, was reappointed Secretary-Treasurer.

At the morning session Hon. L. C. L. Smith, engineer member of the Sanitary Commission of New York City, gave a very interesting paper on the "Governing Features of the Sewage Treatment Plan for New York City." This was followed by a symposium "Sludge Handling," in which Mr. W. Donaldson spoke on "Activated Sludge," Fred J. Biele on "Sludge Pumping," W. Gavett on "Sludge and Gas Production," G. E. Hill on "Sludge Drying" and R. S. Rankin on "Sludge Collection from Settling Tanks." M. M. Aboul Ela of the Municipal Engineering staff of Alexandria, Egypt, spoke briefly on the "General Problem of Sewage Disposal in Egypt" and his interest in the sewage treatment works in this country.

At the luncheon Dr. Carl E. Buck of the American Public Health Association gave a very interesting talk on "Recent Developments in Public Health Administration." Mr. C. A. Emerson, Chairman of the Board of Control of the Federation of Sewage Works Associations, spoke on the work of the Federation.

At the Round Table Discussion in the afternoon session, J. F. Skinner led the discussion on "Sewage Sludge as a Fertilizer." Earl Devendorf opened the discussion on "New Kinks in Plant Operation," and L. H.

Enslow led the discussion on "Chlorination for B. O. D. Reduction." A large number of those present took part in the discussion, so that the closing time of the meeting had to be considerably extended.

In the evening members and guests of the Association joined with the Sanitary Engineering Division of the American Society of Civil Engineers in the annual dinner of the latter, at which the Hon. L. C. L. Smith was the principal speaker, and at which Professor Bartow presided.

The next meeting of the Association will be held in Buffalo, N. Y., on June 10–11, 1932.

A. S. BEDELL, *Secretary-Treasurer*

Reviews and Abstracts

H. W. STREETER

The Essen-Rellinghausen Treatment Works and Results of Its Recent Enlargement

By Franz Fries, Senior Engineer, Ruhrverband, Essen, Germany

Gesundh.-Ing., **54**, 661, 681 (November, 1931)

Abstracted by G. P. Edwards

I. General Description

The first Essen-Rellinghausen plant, including six Imhoff tanks with bar screens, grit chamber and sludge beds, was built in 1912. Since the flow has now increased to about five times the original design volume, and because more complete treatment was required, the plant has been enlarged and remodeled so that now only the Imhoff tanks remain from the first installation. The latest enlargement was completed in 1930.

In this plant, gas was first recovered from sludge digestion on a large scale and the activated-sludge process was first used in a practical way on the Continent. The present plant includes a coarse bar screen, a double grit chamber, an aerated grease basin, a settling tank with sludge removal apparatus, separate sludge-digestion tanks, the old Imhoff tanks and a drum screen. Final treatment is accomplished in four aeration tanks and three final settling tanks. A final chlorination plant is also available for use when bacterial disinfection is desirable.

The south section of Essen, with 55,000 population, is tributary to the plant. The district is mainly residential although there are a few industrial plants such as coal mines, iron works and dye plants on the sewerage system, which is of the combined type.

The 24-hour flow is 7,900,000 gallons or 144 gallons per capita per day. The proportion of industrial waste, spring and ground water is about 65 per cent of the total flow. The average analysis of the influent and final effluent as given below indicates the sewage to be of average strength. The dissolved oxygen content of the influent sewage is noteworthy, particularly in connection with the biological treatment. The raw sewage is always alkaline.

The average temperature of the sewage is 59° F. and of the air 50° F. The total dry-weather flow is treated and during storms three times the dry-weather flow is settled, but only one and one-half times the dry-

weather flow is treated by the activated-sludge process. The effluent is discharged into the Ruhr River, 82 ft. from the shore. Biological treatment is required because part of the Essen water supply is collected below the outfall and because, in summer, the flow in the Ruhr decreases to as little as 176 cu. ft. per second.

	Raw Sewage	Activated-Sludge Effluent
	(Parts per Million)	
Suspended solids	180	6
Volatile	151	1
Fixed	29	5
Total solids	1014	953
Volatile	209	183
Fixed	805	771
5-Day B. O. D.—not filtered	310	17
5-Day B. O. D.—filtered	133	17
Sulphates	339	300
pH	7.5	7.2
Dissolved oxygen	5.0	3.0

The excess sludge from the activated-sludge tanks is returned to the raw sewage. The plant has been operated in its present condition since October, 1930.

Bar Screen, Grit Chamber and Grease Basin.—The bar screen, made of rolled iron bars, is 9.0 ft. wide, inclined 1 to 3 and has openings 1.2 in. wide. The bars are cleaned by hand. The screenings, amounting to 35 to 106 cu. ft. per day or 0.35 cu. ft. per capita per year, are loaded into dump carts. The large volume of screenings is due to the fact that the sewage flows about 2 miles through an open ditch and collects a considerable amount of rubbish. The screenings are destroyed in an incinerator.

The grit chamber, relatively short and deep as compared with those formerly installed in the Ruhr District, is 46 ft. long and has a water depth of 3.9 ft. Compressed air is added to aid separation of organic matter from grit. The grit is removed by hand and used for fill. An average of 46 cu. ft. of grit per day or 0.30 cu. ft. per capita per year has been deposited. (Munich has 0.16 cu. ft. and the Ruhr District up to 0.53 cu. ft. per capita per year.) Although this grit chamber has been satisfactory, in general, long shallow channels are preferable because of their simplicity.

The grease-removal basin consists of a central aerated channel, with trapped quiescent side channels separated from the central channel by longitudinal baffles, which do not quite reach to the bottom. The water level in the center channel is slightly raised by aeration so that there is a small flow over weirs into the side chambers, where the grease is collected. A stilling chamber precedes the aerated channel in order to intercept large discharges of mineral oil.

The detention period of the grease-removal basin is about 5 minutes based on the dry-weather flow. The air required is 0.013 cu. ft. per gallon of sewage. Mineral oil is burned with the screenings. The grease is conveyed to the digestion tank with the fresh sludge. About 2.1 cu. ft. of grease are obtained each day. The moisture varies between 65 and 90 per cent and fat content averages 45 to 60 per cent. About 22 per cent of the fat is saponifiable. Removal of grease facilitates biological treatment.

Imhoff Tanks.—From the grease trap the sewage flows partly to the Imhoff tanks and partly to the shallow settling tanks, the proportion being 1:5. The effective settling capacity of the Imhoff tanks is 11,300 cu. ft. and the sludge capacity is 33,500 cu. ft. During dry weather the settling period is 1.5 hours.

About 350 cu. ft. of digested sludge, with a water content of 82 to 90 per cent, is drawn daily from the Imhoff tanks. The fresh solids together with the excess activated sludge amount to about 1000 cu. ft. per day. The average digestion period is 47 days. Wooden grids under the gas domes successfully prevent the formation of scum.

Single Story Tanks.—The shallow settling tank is approximately 95 ft. square and is 9 ft. deep at the center. The tank, with an effective capacity of 555,000 gallons and with a flow of approximately 10 cu. ft. per second, has a detention period of two hours.

The settled sludge is forced toward the center by Dorr apparatus into a sludge collection chamber which has a capacity of 2800 cu. ft. The sludge is pumped once daily from the sludge chamber to two digestion tanks. Ripe sludge can be mixed with the fresh sludge from the collection chamber before it passes to the digestion tank.

The flow through the settling tank is equally distributed by baffles. Two overflow weirs on the effluent side are fixed at different elevations, the lower being used during dry weather flow and the other only during storms. Scum is collected on the surface by the Dorr mechanism. The power required for the sludge removal apparatus, which operates continuously, is 2 horsepower.

Separate Digestion Tanks.—The two separate-digestion tanks are circular, with an inside diameter of 49 ft. and an effective capacity of 49,400 cu. ft. each. One tank has a flat bottom and the other a conical bottom sloping toward the center. These tanks can be operated either independently or in series. The sludge in the flat-bottom tank is conveyed to the draw-off pipe in the center by Dorr apparatus. Both tanks are equipped for gas collection. They can be heated by the addition of hot water either directly into the tank or through coils. The sludge can also be circulated by an outside pump. The supernatant liquor is pumped back to the settling tank.

In two-stage operation only the first stage need be heated since the sludge transferred to the second stage contains sufficient heat to maintain rapid digestion.

About 2900 gallons of hot water is added daily to the first stage to maintain an average temperature of 73° F. About 5650 cu. ft. of gas per day, or one-third of the total produced, is required to heat the tank.

The power required for the sludge removal and scum breaking apparatus is about 1.7 horsepower. In the second stage, where the scum breaker is used only 1 to 2 hours daily, the power required is only 0.8 horsepower. Sludge is pumped by air-lift from the second stage to drying beds.

An average of 2470 cu. ft. of fresh solids and 3880 cu. ft. of excess activated sludge, making a total of 6350 cu. ft. with a moisture content of 97 per cent, are collected each day. By concentrating the sludge to 94 per cent moisture in the collection chamber, the volume is reduced about 50 per cent. This concentrated sludge is added once daily to the first-stage digestion tank. From the first stage 2295 cu. ft. of sludge, containing 92.5 per cent moisture, passes daily to the second stage, from which 1412 cu. ft. of digested sludge containing approximately 90 per cent water is drawn. The volume originally added to the first stage is thus reduced about 55 per cent. The temperature in the heated first stage is about 14° F. warmer than in the Imhoff tanks and 7° F. warmer than in the second stage.

The supernatant liquor from each tank averages 880 cu. ft. per day. The digestion period is 18 days in the first stage and 26 days in the second.

Sludge Drying Beds and Fields.—The amount of digested sludge has been increasing each year so that its disposal is always a problem. At first the sludge was dried on beds, to which it flowed by gravity. The dried sludge was stored and used for fertilizer. This has been impossible since 1925, when the activated-sludge plant was put into operation, because of the increase in sludge volume and because part of the land was needed as a site for the activated-sludge plant. As a substitute for this space, new beds 21,530 sq. ft. in area, or 0.38 sq. ft. per capita, were constructed and connected to the treatment plant by a pipe 2620 ft. long and about 5.0 inches in diameter. This space is not all in use now but is held in reserve for rainy seasons since liquid sludge can be added directly to arable land. About 28.4 acres of field are available. The land receiving sludge is not cultivated for one year. During the first year sludge was spread on 5.7 acres, so that every fifth year the land again receives sludge. How this plan will work out remains to be seen.

About 635,700 cu. ft. of sludge must be dried each year. Spread on 5.7 acres or 248,300 sq. ft. it amounts to a depth of 2 ft. while wet, or about 4 inches when dried to 40 per cent moisture. There is a total surface of

about 21.5 sq. ft. per capita available, although at present only 4.5 sq. ft. per capita are used. The nitrogen content of the sludge averages 2.5 per cent.

Gas Collection.—The gas collected is added to the city supply. Based on the yearly average, 31,270 cu. ft. of gas is collected per day, equivalent to 0.56 cu. ft. per capita. This amount of gas is sufficient to cover the power needs of the whole plant. The gas contains about 28.4 per cent CO_2, 0.2 per cent CO, 6.8 per cent CH_4 and 3.4 per cent N. The heat value averages 715 B. t. u.

Activated Sludge.—The four aeration tanks are fitted with porous plates and paddles lying under the water. The shafts and paddles are made of wood, mostly pine rich in resins. The paddles make 7 revolutions per minute, which corresponds to a peripheral speed of 2.4 ft. per second. The two long rows of filter plates are arranged in the center of the bottom of the tanks in such a way that the air which naturally rises vertically is caught by the paddles and intimately mixed with the tank contents. The air bubbles remain longer in contact with the liquid and Sierp's experiments have shown that 30 per cent of the oxygen is transferred to the water, whereas with simple aeration only about 5 per cent is used up. The paddles also hold the sludge in suspension. A 5 hp. motor is used to operate the paddles of each tank.

The filter plate surface is 430 sq. ft. or one-thirtieth of the total tank surface. About 0.065 cu. ft. of air is used per gallon of sewage with 2.9 hours' aeration.

Three Dortmund radial-flow tanks serve for secondary settling. The two old tanks are about 26 ft. deep. The new one, which is only about 20 ft. deep, is not as satisfactory. During dry weather the settling period is 80 minutes. The returned sludge amounts to 23 per cent of the average flow. The activated sludge in the aeration tank, measured after one hour settling, is only 6 to 8 per cent of the tank contents. The aeration tanks give better results if some dilution water containing oxygen is returned with the sludge. For instance, if 7 per cent sludge (settled 1 hour) is returned, 11.5 per cent dilution water should be added.

Pumping the excess sludge back to the preliminary settling tank with the sewage has been satisfactory. Difficulties were encountered when the excess sludge was discharged directly into the digestion tank. There is about 34,350 gallons of excess sludge per day, containing 98 per cent moisture. On a dry basis, this is 92 cu. ft.

The total power required for aeration, stirring apparatus and pumps for returned sludge amounts to 7 hp. per million gallons. Power needs have not increased with heavier loading of the plant. Purification, as shown by the oxygen demand of the filtered raw and effluent samples, is 92–98 per cent. The effluent is always clear and stable.

Incinerator.—Screenings and part of the skimmings from the grease trap are burned. About 120 lbs. of coke must be used to burn one ton of material. Ash amounts to about 3.5 per cent of the original volume.

II. Operating Results

Presettling and Sludge Treatment.—The settling efficiency of Imhoff and shallow settling tanks is generally the same, varying from 95 to 98 per cent, based on settleable solids. The efficiency of a separate settling tank is lower if the sludge removal apparatus is not used continuously, since the layer of sludge which forms on the bottom is stirred up by the scrapers. Continued operation of sludge removal apparatus is particularly necessary when excess activated sludge is added, as this sludge often bulks soon after settling, probably because of lack of oxygen.

A sludge-collection chamber under the settling tank facilitates operation if designed so that sludge cannot re-enter the settling compartment. The collection chamber obviates frequent pumping of sludge and concentrates the sludge to about 50 per cent of the original volume. The scrapers do not seem to concentrate the sludge. For settling, rectangular tanks with flow from one end to the other are simpler than round ones with radial flow, since the syphon carrying sewage to the center is eliminated and since the shorter overflow weir is less subject to disturbances caused by settling of the ground. The latter is especially true in mining communities. Circular tanks seem to be unsatisfactory because settling is disturbed when the sludge removal apparatus moves past the entire length of the overflow weir.

The effective digestion capacity was increased from 62,775 cu. ft. to about 133,400 cu. ft. so there is now available about 2.4 cu. ft. per capita. The gas yield has been more than doubled by increasing the digestion period but the water content of the sludge remains the same, due to the activated sludge.

About 0.36 per cent of the sewage flow as fresh solids and activated sludge goes to the digestion tank and 0.16 per cent is withdrawn as digested sludge. The organic content is reduced about 40 per cent in the digestion tanks.

The two-stage digestion process has been satisfactory, especially since it has the advantage of being economical in the use of heat. About 70 per cent of the total gas is obtained in the first stage. Continuous use of the stirring apparatus permits equal distribution of heat, and assures collection of gas at a uniform rate. It also causes intimate mixing of the fresh solids with the ripe.

In the second stage, the sludge is circulated once daily by a screw pump placed outside the tank. This vertical circulation has not been satisfactory since the sludge liquor becomes mixed with the settled sludge and no supernatant liquor can be withdrawn.

Biological Secondary Purification.—Activated sludge is the most efficient biological treatment, especially on a unit surface basis. About 610 gallons of sewage per square foot can be treated by activated sludge whereas sprinkling filters can treat only one-tenth this amount. Odors and flies often appear with sprinkling filters. The efficiency of activated sludge is enhanced by removal of the solids from the raw sewage. Continuous aeration is necessary and the air needed is definitely related to the composition of the sewage. Cold does not seem to affect the operation of an activated-sludge plant. During the relatively cold winter of 1929, when the air temperature dropped to −4° F. and the sewage temperature went to 46° F., the tanks gave the usual good results. During high temperatures in summer, the purification is occasionally slowed up.

To maintain the highest efficiency of activated sludge, it is essential that there be no pockets where sludge can become septic. Sludge from the secondary settling tank should be returned to the aeration tank as rapidly as possible. Long sludge pipes should be avoided. In the Rellinghausen plant, the return sludge passes through an open channel 26 ft. long. Since the sewage in this channel contains dissolved oxygen, part of the oxygen requirements of the sludge is satisfied and the sewage itself undergoes a sort of preliminary treatment.

In judging what type of aeration is best, it must be considered that the longer air remains in contact with sewage, the more oxygen is dissolved. Simple surface aeration is not always satisfactory. Care should be taken, however, in comparing various systems when they are operated under different conditions.

III. Costs

The construction costs for the original Essen-Rellinghausen Treatment Plant and its remodeling and enlargements were as follows:

Screens, grit chamber and grease trap	$ 10,000
Imhoff tanks	37,500
Preliminary settling tank with Dorr equipment, separate-digestion tanks, sludge pumps, pipes and heating plant	100,000
Sludge-drying beds and apparatus for distributing sludge on land	15,000
Activated-sludge plant with aeration and secondary settling tanks	100,000
Other machinery	12,500
(4 Marks = 1 Dollar) Total	$275,000

This amounts to $5.00 per capita. In comparing these construction costs with those of other plants, it should be considered that volume of sewage treated here is equivalent to that expected from 150,000 population under normal conditions. The annual operating costs are $22,500 or about $.28 per capita.

Operating Results and Experience with Separate Sludge Digestion at the Essen-Frohnhausen Plant

BY DR. ING. W. HUSMANN, Chemist, Emschergenossenschaft, Essen, Germany

Gesundh.-Ing., **54**, 736 (1931)

ABSTRACTED BY G. P. EDWARDS

The Essen-Frohnhausen treatment plant treats the sewage from about 50,000 inhabitants. It is mainly domestic sewage although occasionally small amounts of dye waste are received. The dry weather flow amounts to about 4.3 cu. ft. per second. Half of the sewage is settled in old Imhoff tanks and the other half passes through the new plant with its separate sludge digestion.

The dry-weather flow has a detention period of about $1^1/_2$ hours in the settling tanks, which lie on both sides of the digestion tank. At this rate, satisfactory clarification is obtained at all times. The settleable solids, as measured in Imhoff cones with one hour settling, show as an average for 1928–31, 6.8 cc. per liter for the raw sewage and 0.19 cc. for the effluent, or 97.1 per cent removal. An average for the same period showed 520 p. p. m. suspended solids, of which 365 p. p. m. were volatile, for the raw sewage and 175 p. p. m. total suspended matter with 130 p. p. m. volatile in the effluent. These results indicate 66.3 per cent removal.

The amount of fresh solids pumped daily to the digestion tank is fairly constant and averages about 880 to 1060 cu. ft. More sludge is pumped at the beginning of the week than at other times since no fresh solids are passed to the digestion tank on Sunday. The portable pump has been quite satisfactory. The fresh solids average 94.4 per cent moisture. The solids are 68.2 per cent volatile and the pH is 6.06. If this acid sludge were discharged into a digestion tank containing well-digested sludge with a pH of 7.0 to 8.0 without mixing the two sludges, acid sludge pockets could form. These would be detrimental to the digestion process. That the entire contents of the tank could become acid, can be constantly observed in the Imhoff tanks of this plant. In order to assure mixing of the contents of this 31,800 cu. ft. digestion tank with the fresh solids, two screw pumps are operated for two hours daily after addition of the fresh solids.

A series of depth samples collected before circulation of sludge showed supernatant liquor containing usually 10 to 25 cc. solids per liter (settled 2 hours) down to about 17 ft. below the surface. Below the sludge line, there was heavy sludge. After two hours' circulation of sludge, samples were collected from the same points. Settling tests showed that the sludge was well mixed with the supernatant liquor As the sludge settles again to the bottom the bacterial decomposition products are washed away and the sludge can digest further. An average digested sludge contains about 17.5

per cent solids of which 40.7 per cent is volatile. The pH varies between 7.0 and 8.0.

This digested sludge dries well and can be lagooned in simple earthen basins to a height of more than 3 feet. In basins of this kind, sludge must be added in layers about 4 in. thick and allowed to dry well before the next layer is added.

In the digestion tank, the sludge concentrates so rapidly that if fresh solids are added and mixed with the ripe sludge by circulation in the morning, sludge liquor can be withdrawn in the late afternoon of the same day. Depth samples collected shortly before sludge liquor is withdrawn show liquor containing from 0.35 to 0.66 per cent solids down to about 14.5 ft. from the surface. At that point, heavy sludge containing 12 per cent solids is found.

Fries ("Imhoff tanks and Separate Digestion Tanks in the Last 22 Years," F. Fries, *Gesundh.-Ing.*, **36** and **37** (1928)) states that circulation of sludge in the Imhoff tanks at Essen-Rellinghausen caused the sludge liquor to become so well mixed with the heavy sludge containing 82–90 per cent water that the moisture content of the sludge became uniformly 95 per cent. From Fries's data, it is not clear whether this condition was found only shortly after circulation or whether it was continual during the entire operating period. The period of circulation was not mentioned. If at Rellinghausen, the sludge does not separate from the water when quiet, the condition may be due to the presence of the excess activated sludge or to too prolonged circulation.

The sludge liquor drawn from the tank is gray-green in color and contains about 0.3 per cent solids of which 50 per cent is volatile. The permanganate consumed varies between 300 and 400 p. p. m. The pH varies between 7.0–7.5.

A special settling tank with about 5300 gallons capacity has been installed to remove the sludge completely from the supernatant liquor. The detention period is 4 hours and the effluent passes back through the plant with the raw sewage. In new plants of this type, the floating sludge will be held back in the digestion tank by suitable construction.

Heat from the raw sewage is transferred through the thin walls separating the settling tank and the digestion tank to the digesting sludge. The average temperature for the last three years has been 61° F. The gas obtained has averaged 0.56 cu. ft. per capita per day. This is about twice as much as usually reported. This high yield is due at least in part to circulation of the sludge. Sierp (*Gesundh.-Ing.*, **53**, 810 (1930)) states that the increase in gas yield due to circulation is only 10 to 20 per cent and that this extra amount consists mainly of CO_2. In proof of this, Sierp and others mention laboratory experiments of Bach (*Gesundh.-Ing.*, **48**, 653 (1925)). Bach's results however have been misquoted and really show that the CO_2

content of the gas during daily circulation of the sludge is only about 2.1 per cent higher than when the sludge is allowed to remain quiet. This increase is within the limits of error.

In practical operation six determinations of CO_2 made before, during and after circulation show averages of 30.05, 30.65 and 30.35 per cent, respectively.

The gas obtained from digestion is converted into electrical energy which serves for operation of pumps and compressors.

Power Requirements for Activated Sludge Plants

DR. ING. W. SCHÜTZ, Berlin-Lichterfelde West

Gesundh.-Ing., **54**, 721 (1931)

ABSTRACTED BY G. P. EDWARDS

Operating costs for activated-sludge plants using compressed air can be reduced by decreasing the back pressure. In the Kremer air circulator, this is done by introducing the air only 2.75 ft. below the surface. In the upper part of the circulator, the air-water mixture, which forms, is lighter than water and the operating back pressure is equivalent to only 1.8 ft. of water as measurements at the Templin treatment plant have shown. This pressure of $2.75 - 1.80 = 0.95$ ft. of water forces the sludge liquor into the suction pipe and causes continuous circulation. Besides the operating back pressure, there is resistance due to the nozzle, which is equivalent to 3.1 inches of water. This is much less than the resistance due to filter plates. The resistance of the pipe and air meter can be omitted since they are the same for all systems. The only other factor in the power needs is the air required per unit time. With normal sewage, the Kremer circulator must furnish 1.56 cu. ft. of air per gallon of sewage. With air filter plate distribution only about 0.8 to 1.0 cu. ft. of air per gallon of sewage is needed.

The Templin treatment works treat 264,000 gal. per day, with a maximum hourly flow of about 26,400 gallons, from a population of 10,000 by the Kremer system. The aeration tank has a capacity of 111,000 gallons with a tank depth of 11 ft. About 1.56 cu. ft. of air are used per gallon of sewage and the power required is 4.65 kw.

A filter plate aeration tank corresponding in size uses 0.78 cu. ft. of air per gallon of sewage. With a depth of 11 ft. the back pressure, including filter plate resistance, is about 12.3 ft. The power needed then amounts to about 12.5 kw. or 2.7 times as much as with the Kremer system.

For small plants such as at Rabenstein, a community of 3000 people, a Kremer system has also been satisfactory with the power required

slightly more than one-third of that needed with filter-plate distribution.

In large plants, the circulators placed at the side of the tanks instead of the middle impart a circular motion to the liquid. At the Templin plant, there are 42 circulators. Each lifts about 5280 gallons of sewage with 106 cu. ft. of air making a total of 222,000 gallons of sewage circulated per hour. The amount circulated can be increased within wide limits for large plants by using larger circulator units.

The Kremer system not only needs less power but also operates without cooling water and dust filters. There are no movable parts, insuring long life.

Kremer apparatus has been installed at the Kempen treatment plant of the Niersverband for two-stage operation. No data are yet available.

The Limitations of the B. O. D. Determination

BY DR. HERMANN BACH, Chief Chemist of the Emschergenossenschaft, Essen

Gesundh.-Ing., **54**, 41–45 (January 17, 1931)

ABSTRACTED BY H. GLADYS SWOPE

The author found that the biochemical oxygen demand results, as determined by the dilution method, were entirely out of line with other analytical data for judging the pollution of waters. The B. O. D. value varied according to the dilution used, the higher dilutions giving the higher results.

In order to study the cause of these discrepancies an artificial sewage was prepared. Old nutrient gelatine was dissolved in warm water and diluted so that the material would have an oxygen consumed value by permanganate of about 1000 p. p. m. The liquid was seeded with 1 cc. of settled domestic sewage and after 24 hours was filtered. The dilution water used for the B. O. D. test was Essen tap water aerated for 18 hours and 500 p. p. m. of sodium carbonate added. The water was aerated twice more after intervals of 48 hours. The B. O. D. was determined after 20 days in order to avoid 5-day periods which should fall on Sunday; the error in 19- or 21-day demand was assumed to be less than 4- or 6-day incubations. The 20-day demand was also assumed to be the complete demand. The results obtained were very erratic.

Dr. Bach considers that the discrepancies between dilutions may be due to the possibility that in greater dilutions the bacteria have greater freedom and possibly increase, thereby consuming more oxygen.

A true B. O. D. value can be obtained only when dilution is unnecessary, and since there must be residual oxygen at the end of the test, only slightly

polluted waters can be accurately examined. To obviate this difficulty easily reducible compounds containing a proportionately large amount of oxygen could be used. Nitrates have been tried in America, but with very concentrated sewages a large amount of the salt is necessary and this hinders bacterial activity and again dilution would be necessary.

The Sierp method does not require dilution but its technique is complicated and therefore is inapplicable for routine work. This method has the advantage that the demand can be determined from day to day. It does not approach natural conditions in that pure oxygen is fed to the apparatus whereas air, which diffuses into a stream, is a mixture of gases. The method has not been studied in Germany outside of Dr. Sierp's laboratory but in America the method has been considered excellent for research work but in no way adapted for routine work in its present form.

Dr. Bach sums up his paper by stating that one must be very cautious when attempting to draw conclusions from B. O. D. results.

Vom Wasser

ABSTRACTED BY G. P. EDWARDS

The 1931 edition of "Vom Wasser," the year book published by the Water Chemistry Group of the German Chemical Society contains the following papers relating to sewage treatment.

Recent Results of Investigations of the Effect of Cellulose Factory Wastes on Fish. DR. G. EBELING (Berlin-Friedrichshagen) p. 192.—Although the waste from the acid sulphite process has a permanganate consuming power of 48,600 p. p. m., when fresh waste is diluted 1:2 with water, it does not seem to be harmful to fish. However, the waste from the sodium sulphate process, with a permanganate consuming value of 610 p. p. m., is poisonious to fish when diluted 1:2 with water. In the sulphite process, more spruce is used than pine. Pine contains about 3 per cent resins whereas spruce contains only about 2 per cent. Resinic acid is harmful to fish in dilutions of 1:200,000.

The Influence of Sewage Chlorination on Streams Containing Fish. DR. G. EBELING (Berlin-Friedrichshagen) p. 201.—Various fish were placed in tanks of water containing 1 p. p. m. of free chlorine and having a pH value of 7.2–7.6 and temperature between 4.5–7.0° C. Pike were most sensitive, succumbing in about 30 hours and trout died in 37–40 hours. Of fifteen carp, seven died in about 100 hours. Eels apparently were not affected. With only 0.15–0.20 p. p. m. chlorine, carp were not affected at 10–15° C., one-fourth of the carp died in 12–16 days from chlorine poisoning.

Three Years' Results of Operation of the Leipzig Settling Tanks. F. MIEDER, p. 212.—The settling-tank plants I and II, which are more than 30 years old, are manually cleaned and are insufficient for the increased amount of sewage and industrial wastes. For additional settling capacity, shallow tanks, 180 ft. long, with mechanical sludge removal were chosen. A scraper half submerged in water moves across the tank toward the effluent end at a speed of about 3 inches per second, forcing the scum into a trap. The scraper then slowly sinks to the bottom and moves at a rate of about 0.8 inch per second toward the influent and pushing the sludge into a sump which reaches about one-third the distance from the influent of the tank. By slowly lowering the scraper and reducing the speed of movement, no sludge is stirred up. No sludge has been observed to pile up over the scraper and to settle on the back side of it. The scraper is nearly 36 inches high. It has been determined that the sludge depositing in 24 hours never reaches a height of more than 10 inches and during collection never is higher than 20–24 inches. The collection of scum requires about 10 minutes and its removal about 5 minutes more. The return of the apparatus for sludge removal takes about 45 minutes. Not more than 1.5 H. P. are required. The apparatus can be moved from tank to tank. Uniform distribution of the incoming sewage is most important and is obtained by the use of baffles arranged like Venetian blinds. The tanks should be as long as possible so that the whirling motion caused by the incoming sewage should not reach the effluent end. The old tanks are quite efficient immediately after cleaning. Before cleaning or during storm flows, they are much inferior to the new ones. During heavy load, the new tanks retain 97 per cent of the settleable solids whereas the old ones retain only 93 per cent. The moisture of the sludge in each case is about 90 per cent, although in the old tanks the sludge may be 10–14 days old. About 35–70 cu. ft. of scum is obtained daily from the new tanks. The cost of cleaning a tank mechanically, including interest and depreciation, is about 50 per cent as much as cleaning by hand. The mechanical apparatus has been very satisfactory during its three years of operation Similar equipment has been installed by Berlin and Nuremberg as well as by the Niersverband.

Clarification Apparatus with Flow Regulation. DR. R. VAN DER LEEDEN (Neumünster), p. 229.—Experiments of the Prussian Landesanstalt für Wasser, Boden and Lufthygiene have developed a settling tank for small installations featuring automatic control of flow and chlorination by floats and valves.

New Results from the Experimental Activated Sludge Plant in Leipzig. F. MIEDER AND DR. K. VIEHL, p. 236.—The original experimental plant consisted of two small aeration tanks 6.5 ft. wide, 6.5 ft. deep and 65.6 ft. long. One tank was fitted for spiral flow aeration and the other for paddle-wheel aeration. The paddle wheels moved at the rate of 7 revolutions

per minute. Following were two funnel shaped tanks with an effective capacity of about 880 cu. ft. The raw sewage was settled in Imhoff tanks before flowing to the aeration tanks. With weak sewage only 0.07–0.13 cu. ft. of air per gallon is necessary. This is not enough to circulate the sludge-sewage mixture so that stirring may be cheaply done with paddles. At Leipzig, however, the sewage is so concentrated that the air necessary for purification is also sufficient for circulation of sludge and the paddle wheel is superfluous. Aeration of the entire dry weather flow of Leipzig in paddle-wheel tanks, using only 0.26 cu. ft. of air per gal. of sewage, would cost about $200,000 per year including interest and depreciation. Under the same conditions, expenditures for a plant using the spiral-flow system would amount to only $^5/_8$ of this sum.

The sludge in the aeration tanks is very dilute, having an average moisture content of 99.2 per cent. This condition requires more settling and digestion space and greater sludge pumping capacity. Ferric chloride in large amounts made the sludge more compact but only as long as the chemical was added. Prechlorination was not successful but occasional additions of hydrochloric acid to a pH of 6.5 caused the sludge to become more compact without injuring the protozoa. The bulkiness was found to be due in part to *Sphaerotilus*, which can be removed by additions of approximately 1 p. p. m. of copper sulphate to the effluent. Protozoa are only slightly affected. The sludge becomes compact for a time but generally again assumes its bulkiness.

From July to September, 1930, the spiral-flow tank contained a large amount of chironomus larvae which caused balling of the sludge. The paddle wheel in the other aeration tank prevented the maturing of the eggs.

In another tank, with a capacity of 6700 cu. ft., four wooden paddles on a common shaft were installed on the surface. The paddles beat air into the liquid as well as scooping up part of the sludge liquor and throwing it, finely divided, into the air over the surface. The power required was about 5 hp. Even with a 12-hour aeration period the process was not satisfactory. Air was then added through 16 porous plates placed on the bottom of the tank at the side opposite to that occupied by the paddles. A relatively small amount of air (0.26 cu. ft. air per gallon sewage) made possible such a reduction in the aeration period that it was about 20 per cent less than in the other tanks which were operated under the same conditions.

Brushwood and coke or slag, and later laths and pieces of cork, were used in submerged contact aerators when one of the aeration tanks was rebuilt. Laths placed diagonally on a frame gave the most uniform air distribution. Used as pretreatment to activated sludge, the total aeration period was reduced only slightly. However, with pretreatment the activated-sludge stage works more uniformly with sewage of varying strength. The sub-

merged contact aerator reduced the permanganate demand of the sewage 24 per cent and the oxygen demand about 40 per cent. The effluent was usually turbid and not stable.

How Should Sewage Treatment Plants Be Investigated? DR. H. BACH (Essen), p. 258.—A thorough knowledge of local conditions is necessary in order to study a sewage treatment plant. The determination of total and suitable suspended solids in the raw as well as in the settled sewage is most important for mechanical treatment plants. Not the per cent reduction but the absolute content of suspended solids in the clarified sewage is the deciding factor. If the effect of the sewage on a stream is to be investigated, then the insoluble as well as the soluble constituents of the sewage are of interest. The stages of treatment such as coarse or fine screens, grit chambers, distribution channels and clarification tanks should also be examined. In biological treatment plants, a special plan is generally necessary for each case. The fertilizing value of sludge depends at least as much on the humus as on the nitrogen, potash and phosphoric acid.

The Re-Use of City Sewage

BY DR. ING. KARL IMHOFF, RUHRVERBAND, ESSEN

Gesundh.-Ing., **54**, 699–703 (Nov. 21, 1931)

ABSTRACTED BY J. K. HOSKINS

Although the repeated use of the same water in industry is accepted practice, such re-use of city sewage for drinking water is not generally favored. However, in densely populated areas it is not always possible to obtain unpolluted water as sources for city supplies, although this state of affairs results in no detrimental effects. Los Angeles is confronted with the problem of making additional use of its limited water resources because of the rapid growth of the city, the scarcity of ground water and the great distance over which additional pure supplies must be transported. Wilson and Goudey, from extensive experiments, have determined that the city can produce good drinking water from its sewage at less than one-eighth of the cost of the distant fresh water. The sewage treatment outlined consists of sedimentation, activated sludge, chemical precipitation, chlorination, sand filters and activated carbon. Such purified sewage differs in no way from the best drinking water. Wilson and Goudey propose to use such recovered water for a part of the city's requirements.

Although this procedure appears venturesome it is in fact not unusual because many of the larger supplies in Europe and America are from rivers and often nothing more than diluted sewage contributed by upstream

populations. Examples of this water-sewage-water cycle are the Ohio River in America and the Rhine, the Elbe and the Ruhr in Germany.

In normal watercourses the sewage component usually forms a small fraction of the total fluid but in times of drought this fraction rapidly increases, as illustrated by the Ruhr in 1929 where in a stretch of 90 km. the drinking water-sewage cycle for the entire volume of flow was repeated three times. Moreover the time for completion of each cycle was shorter than the preceding one, averaging 12 days. The purification processes active in this re-use cycle of the Ruhr water consisted of:

1. Part mechanical and part biological sewage treatment in the works of the Ruhrverband,
2. Biological self-purification in the stream,
3. Earth filtration in the natural ground filters of the water works.

These processes of purification were entirely adequate; the drinking water was of good quality and tasteless, and the typhoid cases were never lower than during this dry period.

In view of the existence of this cyclic re-use of water the question arises as to how often the cycle may be repeated, because obviously there must be a limit. Certain constituents such as chlorides are not removed in the re-purification processes and hence eventually would reach a limit of tolerance.

Dr. Sierp has conducted certain experiments to ascertain this limit of re-use, the results of which are given and which indicate that in the eleventh cycle the chlorine content of the treated water reaches a point (380 p. p. m.) beyond which the use for domestic purposes is prohibitive on account of salty taste. It seems probable therefore that about ten cycles is all that can be expected to be practicable.

In a new series of experiments chemical precipitation with chlorine is being tried to bring the water to comparable purity with pure drinking water. It is expected that the 9-day cycle can be considerably shortened by this means. These experiments determine that it is entirely feasible from the water purification standpoint to purify and re-use the city sewage up to ten times in the water-sewage cycle, which means that a city need provide only 10 per cent of its water needs in the form of a fresh supply and waste 10 per cent of its sewage, repurifying the remainder for re-use as drinking water.

Dr. Abel, professor of hygiene at Jena, takes strong exception to the conclusions of Dr. Imhoff regarding the use of treated sewage as drinking water. He insists that from the hygienic standpoint this is an entirely impossible procedure. Civilized human beings will not consent to the ingestion of their own urine and that of their fellows however masked or treated. Palatability is the prime essential of any drinking water supply worthy of the name and must be taken into account. The erudite professor states that such a treated sewage supply may be all right for Los Angeles, in

a land whose people are the least cultured of any in the world claiming civilization, but for Germany (presumably highly intelligent) no, indeed!

Dr. Imhoff in his reply states that he had not advocated the 10-cycle re-use of sewage as drinking water for Germany but had stated that such experiments were of value in pointing out the possibilities in arid countries. He also adds that in the technic of water supply America has surpassed Germany and that Germany has much to learn from American progress in the art.

The Emschergenossenschaft and the Lippeverband 1925–1930

DR. ING. E. H. HELBING

ABSTRACTED BY G. P. EDWARDS

Dr. Helbing in the booklet "Emschergenossenschaft und Lippeverband in den Jahren 1925 bis 1930" has interestingly reviewed the development of the two districts. The report is profusely illustrated and attractively presented. Photographs portray the improvements in the Emscher River and tributary streams while diagrams show the recent developments along technical lines. Important data on the treatment plants are summarized in a table.

The drainage area of the Emscher River, a tributary of the Rhine, is located in the heart of the Rhenish-Westphalian industrial section and covers about 300 sq. miles. Although complaints of stream conditions in this section date back to the 17th century, conditions have become much worse during recent years since the phenomenal growth in population and industry. The population has reached 2,300,000 and the number of mines, blast furnaces and other industries show a corresponding increase.

The Emschergenossenschaft was organized in 1904 for the regulation of streams and the purification of sewage. Original estimates called for expenditures amounting to about $7,000,000 including approximately $1,100,000 for treatment plants. To date, nearly $44,000,000 has been spent for treatment plants alone. About 45 miles of the Emscher River and 150 miles of tributary streams have been improved. There are 24 pumping stations and 25 sewage treatment plants to serve 2,000,000 inhabitants.

The Lippeverband which has controlled the drainage area of the Lippeverband since its organization in 1927, is closely allied with the Emschergenossenschaft.

Most of the treatment plants are mechanical, as the Emscher River is not used for water supply. The earlier plants were of the Imhoff type but recently the tendency has been toward separate digestion tanks with

artificial heating and circulation of sludge to hasten digestion and increase the gas yield. By circulating only the liquor in the upper part of the tank and by drawing from the lowest point where the sludge is quiescent, the new digestion tanks avoid the withdrawal of fresh sludge after sludge circulation.

Although an attempt is made to remove coal sludge from the liquid wastes at the mine, about 350,000 cu. yds. of wet coal sludge is removed annually from the Emscher River at Karnap near its discharge into the Rhine River. The sludge, containing 50 per cent moisture, is easily dried on earth beds and can be burned.

Although biological treatment is of secondary importance, some of the small plants have sprinkling filter installations.

Phenols are recovered at some coke plants by extraction with benzol. Due to economic conditions, only about 1200 tons of phenol are now obtained.

The Treatment of Sewage Sludge by Bacterial Digestion

BY H. C. WHITEHEAD AND F. R. O'SHAUGHNESSY

Proceedings of the Institution of Civil Engineers, **233**, 1–23 (November, 1931)

ABSTRACTED BY C. C. RUCHHOFT

The purpose of the paper is to discuss critically the large amount of data available on the means of accomplishing anaerobic sludge digestion. The advantages of bacterial sludge digestion to facilitate sludge disposal are the following:

(1) The process causes no smell nuisance.
(2) The difficult physical (colloidal) character of the sludge solids is modified so that they can be dried in the open with relative ease.
(3) The final product is an inoffensive peatlike solid.
(4) The cost is reasonably low.
(5) The results can be obtained with a simple procedure.

The major issues in the application of sludge treatment by digestion are somewhat confused. The confusion has been caused by the accumulation of a large amount of data with only partial statements of the conditions under which the results were obtained. The complete statement of the problem involves information on the intermediate phases of treatment, statistics on sludge gas yields, over-all cost and fate of the digested sludge. While the results of laboratory digestion experiments are valuable the fact remains that results from large-scale operations on the whole show a remarkable lag in comparison to them. This is because it is more difficult

to provide the proper environment for the organisms on a large scale. The major factors influencing the course of digestion of the sludge are water content, temperature and pH. Some laboratory experiments have led to expectations of wide variations in different sludges. Reliable large-scale results, however, seem to show a remarkable uniformity in the behavior of the fermentable portions of sludges from very different localities. Prolonged experience at Birmingham agrees with numerous detailed researches and indicates that the changes which take place in the sludge as it passes through the various stages of digestion are manifold.

Another source of disagreement in results arises from differences in treatment of raw sewage. This is due to differences in the amounts of suspended materials passing through or converted to sludge in the different processes. To compare plant results it is necessary to have the relative amounts of sludge per capita extracted from the sewage and passed through the respective sludge treatment processes. In England with most towns on small streams 90 per cent of the suspended matter must be removed with the sludge. On account of the different amounts of sludge-forming materials that are removed, the criterion of digestion capacity per capita may prove very misleading. A further source of confusion lies in the lack of satisfactory standards of digestion. The ultimate method of disposal of the sludge from the beds determines to some extent the length of the digestion period required.

Temperature is a factor of major economic significance. Digestion is very sluggish below 8° C. and fairly vigorous at 15° C. The authors believe that the optimum rate is reached between 25° to 28° C. but doubt if this is the economic optimum temperature. Economics is the outstanding issue between the alternative temperatures of carrying out the digestion process.

Two-story tanks with depths of 25 feet or more appear to give satisfactory results with domestic sewages in temperate climates. American experience with two-story tanks has not been altogether satisfactory. In Germany where this form of tank has been used for 20 years it has provided an admirable means of sludge digestion. The authors suggest that some of the adverse criticism is due to faulty design, insufficient capacity of digestion chambers and unskilled manipulation.

Experience has shown that separate sludge-digestion tanks are more elastic than two story tanks. Generally control may be maintained without any great difficulty in correctly designed separate digestion plants. Provision for horizontal flow in the digestion chamber and the division into two stages furnishes conditions for what is called biological zoning.

After the biochemical action exhausts the gas-forming constituents of the sludge the digested material settles in the chamber. The digestion procedure must provide for this contingency or embarrassing difficulties

will result. Provision is made for this in the two-story and Birmingham two-stage process. In the Birmingham method the retention in the primary tank is limited (according to the temperature) so as to prevent exhaustion of gas-forming constituents. In this way the accumulation of worked-out sludge in the primary tank is avoided. The exhaustion may occur in the secondary tank without causing embarrassing difficulties.

The danger of drawing off partially digested sludge which exists in single chamber tanks is obviated in the two-stage process. Generally the water content of single-chamber sludges when removed from drying beds is relatively high because of the undestroyed colloids present. Such a sludge even with a moisture content of 50 to 60 per cent may be saleable to farmers. If, however, the dried sludge is to be used for manufacture of fertilizer, complete digestion to obtain a low final water content becomes of great importance. In countries subject to parasitic infection the single-stage process does not afford sufficient protection for laborers engaged in the disposal of the dried digested sludge.

The main factors influencing the design of a sludge digestion plant are:

(1) Quantity of sludge to be treated,
(2) Percentage of organic matter in the sludge,
(3) Fermentability of the sludge,
(4) Water content of the sludge when delivered,
(5) Water content of the sludge during digestion,
(6) Temperature which can be maintained,
(7) Method of disposal of digested sludge,
(8) Utilization of gaseous products.

Information on the first two factors must be obtained by analyses of the sewage and effluent taken over a long period. The fermentability must be determined by laboratory trials.

The water content of the sludge is of great importance as it influences the size of the digestion chamber. Also the lower the water content the more readily will a given amount of heat raise the temperature. A given mass of sludge solids containing 95, 90 and 85 per cent of water will have relative volumes of 3, $1^1/_2$ and 1. The water content of the sludge in a horizontal-flow settling tank varies inversely with the retention period. Modern practice tends toward frequent emptying and a sludge with less than 95 per cent water cannot be obtained in this way.

The control of the water content of the sludge during digestion is important both from the point of view of design and management. Means should be provided and intelligently used for removal from the digestion tanks of surplus water. In this respect two-stage treatment is more convenient than single-stage.

In considering the temperature to be maintained the authors believe that the economic optimum is below 25° C. and that temperature control is of far greater importance at the beginning of the operation than in the later stages. Various means of supplying additional heat are available to the engineer. The degree of temperature to be maintained depends upon the cost of heat, the water content of the sludge, the insulating properties of the tanks and the desirability of utilizing all or part of the gaseous products for power production. If the gas is used for power in internal-combustion engines about 50 per cent of the waste heat in the cooling water and the exhaust gases may be transferred to the sludge.

The method of sludge disposal to be adopted has an important bearing on the degree to which digestion should be carried. The absence of smell and fly nuisance demands complete digestion. Complete digestion is also required if it is desired to use the sludge for fertilizer manufacture. Disposal of sludge to farmers requires the digestion and drying of the sludge to only about 50 per cent moisture content. This shortens the digestion period and such a plant will have a lower alkalinity reserve, which makes it more sensitive to changes in temperature and operating rates.

The utilization of gaseous products should be considered from an economic point of view. The most profitable use for gas is usually found at the sewage plant for power purposes or for raising the temperature of the digesting sludge. The gas may also be mixed with the town supply if the latter is large. At Birmingham 58 million cubic feet of gas were collected during the year ending May 31, 1931. This represented the primary digestion gas yield from a population of 400,000.

The Works of the Birmingham, Tame and Rea District Drainage Board

BY H. C. WHITEHEAD

J. Inst. of Municipal and County Eng. Proc., **58**, 68 (1931)

ABSTRACTED BY G. P. EDWARDS

(Photographs received by Langdon Pearse from H. C. Whitehead, Engineer to the Board)

The Board created in 1877 has jurisdiction over a district 107 sq. miles in area containing a population of 1,200,000. There are three treatment works. The main one in the Tame Valley includes works at Saltley, Ashold, Tyburn and Minworth and treats a dry weather flow of 30,000,000 gallons (Imperial) per day. Two plants in the Cole Valley at Colehall and Acock's Green provide treatment for a dry weather flow of 3,300,000 gals. (Imp.) per day.

The following table gives an average of a year's analyses of raw sewage from Saltley expressed in parts per million:

Suspended Solids	Free Ammonia	Albuminoid Ammonia	Chlorine	Oxygen Absorbed in 4 Hrs. Unsettled	Oxygen Absorbed in 4 Hrs. Settled	Alkalinity
470	44.4	14.5	163	200.3	156	257

This is characterized by the Ministry of Health as strong sewage.

The sewage at Saltley passes through a rough bar screen with 7-inch openings before flowing to the detritus pit, which is V-shaped in cross section, 240 ft. long, 14 ft. wide at the surface and 19 ft. deep. It is mechanically cleaned. The sewage then flows through five primary settling tanks operated in parallel and then through three secondary tanks, also in parallel. The latter set of tanks has a large reserve capacity and acts as a balancing tank, thus insuring a fairly uniform rate of discharge to the aeration tanks and sprinkling filters. The combined capacity of all sedimentation tanks is 12,500,000 (Imp.) gallons. Each primary tank is cleaned each week and the secondary tanks every two weeks in summer and four weeks in winter.

The primary sludge flows through mechanically cleaned screens to the primary digestion tanks, 27 in number, which have a combined capacity of 144,434 cu. yds. In exceptionally cold weather the temperature of the sludge is raised by injecting steam into the delivery main conveying the raw sludge. The surface scum is retained as it conserves heat. During digestion about one-fourth to one-third of the dry solids is destroyed. The pH of the raw sludge is as low as 5.5 whereas that of the digested sludge is as high as 8.5. After a time the sludge is drawn and pumped 4 miles to secondary digestion tanks at Minworth. Here digestion is completed and the sludge is discharged on drying beds about 67 acres in extent.

The raw settled sludge contains 91 per cent moisture with 56.8 per cent volatile solids. On leaving the primary digestion tanks, the sludge contains 90.5 per cent moisture with 45.2 per cent volatile. As discharged from the secondary digestion tank, the sludge contains 88.7 per cent moisture with 41.3 per cent volatile. The dried sludge contains about 35 per cent moisture and about 2.47 per cent nitrogen.

Gas is collected under floating covers, constructed of reinforced concrete, 20 ft. long and 10 ft. wide. During 1930, 55,000,000 cu. ft. of gas, about one-third of the estimated total, were collected under 600 covers. The gas contains 635 B. t. u. per cu. ft. and is utilized in three gas engines, which have a total capacity of 950 horsepower. These engines are coupled to high tension alternators and the energy provided is utilized for power and lighting purposes.

The effluent from the secondary settling tanks is chlorinated in summer with bleaching powder and it then flows by gravity about 4.5 miles to Minworth. There the sewage is again settled and one-third of the effluent

passes to sprinkling filters and the remainder to bio-flocculation tanks. The sprinkling filters are built of hard stone or durable slag. The total area is 43 acres which, with the exception of mechanical distribution on $6^1/_3$ acres, is served by distributing pipes with fixed spray jets. The effluent is settled in humus tanks.

The sewage which flows to the bio-flocculation tanks is aerated one hour in the presence of activated sludge. After settling, the effluent flows to the sprinkling filter. The advantages of preaeration are that the sludge tending to choke the top of the filter is removed and most of the odor is destroyed. The solids carried by the aeration effluent are distributed throughout the bed and increase the efficiency of the biochemical action.

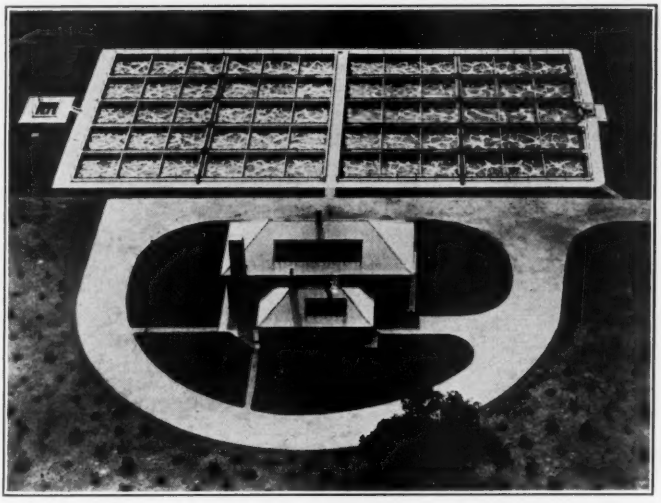

FIG. 1.—Bio-Flocculation Plant No. 2, Birmingham, Aeration Tanks.

The treatment permits $1^1/_4$ million gallons per acre per day to be applied to a filter 6 ft. deep and yields an excellent effluent. Without aeration, the rate is limited to 650,000 gallons per acre per day. With less sludge on top of the bed, fewer flies are found. Less solid matter is discharged from the bed.

The settled activated sludge requires 8 to 9 hours treatment to restore it to full activity. The two aeration plants differ in constructional detail and the means employed for mixing and agitating the liquor and sludge. Plant No. 1, which was completed in 1927, treates 7,500,000 gallons per day and employs both mechanical appliances and diffused air. Inclined paddles at the end of channels, aided by diffused air, provide the aeration.

The sludge conditioning tanks are aerated by diffused air or the Simplex mechanical aeration system.

Plant No. 2, shown in the illustrations, was put into operation in June, 1931. It operates entirely on the diffused-air, ridge-and-furrow system. The excess activated sludge is discharged into the sludge digestion tanks.

The Colehall plant treats about 2,750,000 gallons of sewage per 24 hours from a population of 100,000. The plant consists of six detritus tanks with a total capacity of 100,000 gallons, nine settling tanks with a total capacity of 2,000,000 gallons and three storm water tanks of 1,500,000 gallons combined capacity. The sprinkling filters consist of 21 rectangular beds of

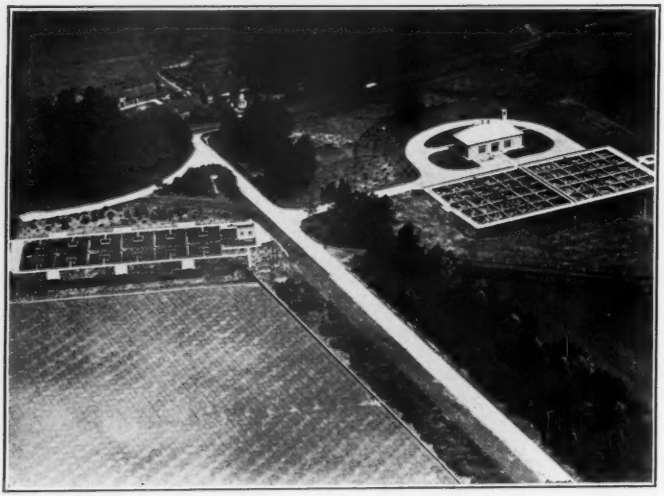

FIG. 2.—Bio-Flocculation Plant No. 2, Birmingham. Aeration Tanks on the Right, Final Settling Tanks at the Left, Sprinkling Filters in the Foreground.

which the total area is $7\frac{1}{4}$ acres and 4 circular beds with a total area of half an acre. The rectangular beds are fitted with traveling distributors. The circular beds contain rotating distributors suspended from a center column and operated on the "Barker's Mill" principle. There are three humus tanks having a total capacity of 750,000 gallons. To improve the effluent, it flows through beds of grass before entering the River Cole. The sludge from the settling tanks discharges into a well and is pumped directly to sludge drying beds.

The treatment plant at Acocks Green treats about 550,000 gallons per day from a population of about 22,000. The sewage is settled and passed through sprinkling filters. The total loans negotiated for purchase of

land, construction of works and provision of plant and machinery to March 31, 1930, was £2,140,205. Of this sum, £1,163,398 has been repaid. The estimated cost of the Board's work during 1930–1931 is £181,990.

Seventieth Annual Report, Birmingham, Tame and Rea District Drainage Board (Brit.)

(1930–1931)

ABSTRACTED BY H. W. STREETER

The Board has lately considered improving methods of sludge disposal at the Colehall Works, in order to obviate a tendency to nuisance at certain times of the year, and having regard for the imminent establishment of a housing estate in proximity to these works. The Colehall Works deal with a population estimated at 100,000 and the dry weather flow of sewage at present is about 2.75 mil. gals. (Imperial) per 24 hours. A scheme has been designed and is now being executed, comprising digestion of sludge and the utilization of gas for power, on lines of the plant now operating successfully at the main works at Saltley.

The scheme provides for construction of seven primary digestion tanks, each 31 ft. wide and 61 ft. long, and equipped with floating iron gas collectors covering the full area of the tank; four secondary digestion tanks, each also 31 ft. by 61 ft.; the installation of two gas-driven electrically operated pumps and a gas-fired water heating system for raising the temperature of sludge in the primary digestion tanks, especially in the winter, and thereby accelerating the digestion process.

The method of operating the plant is as follows: Fresh raw sludge from the sedimentation tanks is pumped into a primary digestion tank which has been partially emptied to receive it, and there mixes with the remaining actively fermenting sludge. After the sludge has remained its economical time in the primary digestion tank it is delivered into the secondary digestion tank, where the digestion process is completed. The sludge is then run onto the drying beds where, by filtration and evaporation, the water content is reduced to about 35 per cent, leaving a hard, peatlike material.

During the process of digestion about one-third of the dry solids are converted into liquid and aqueous products. The principal gas formed is methane, which has a calorific value in excess of coal gas. Provision is made for collecting this gas by means of the floating covers above described. The gas will be utilized to generate electric current for power and lighting and a portion of it, to be used in the water heating system for increasing the temperature of primary sludge digestion.

The plant is designed to treat 50,000 cu. yds. of crude sludge per year. The approved outlay is £30,500 and it is expected that the work will be accepted as suitable for unemployment relief. The new plant is expected to be put into service in the fall of 1932.

Sewage Research at Manchester
Annual Report of the Rivers Department, City of Manchester, for the Year Ending March 25, 1931

BY EDWARD ARDERN

ABSTRACTED BY C. C. RUCHHOFT

Laboratory Experiments

Laboratory trials had emphasized the possibilities of rapid thermophilic (50–55° C.) digestion of sludge but had indicated that thermophilic digestion might be adversely effected by trade waste products in the sludge. During the year the following laboratory experiments were made at thermophilic temperatures: (1) The separate digestion of the common components of sewage sludge, (*a*) paper, (*b*) grease, (*c*) fecal matter; (2) The loss of nitrogen which occurs during the digestion of ordinary domestic sewage.

(1) In the experiments on the separate digestion of paper, grease and fecal matter the amount of digested sludge added was sufficient to make the ratio of dry organic matter in it to that in the fresh material 2:1. The water content was adjusted to 94–95 per cent. The dry organic matter in samples of paper, grease and fecal matter was determined. The weights of each required to provide 1.5 grams of dry organic matter were calculated and weighed out into a small conical flask. The dry organic matter in a sample of digested thermophilic sludge was also determined, and the weight required to provide three grams of dry organic matter was added to each material. The same amount of digested sludge was put into a fourth bottle as a control. The flasks were incubated at 52–53° C. and connected to an arrangement for collecting the gas in measuring cylinders over brine saturated with CO_2. This experiment showed in the case of:

(*a*) Paper, that the digestion was exceedingly rapid and practically complete in three days. A total volume of 700 cc. of gas per gram of dry organic matter in the paper was obtained in 10 days.

(*b*) Grease, that the digestion was not so rapid, but a larger volume of gas per gram of dry organic material was finally produced. A total volume of 1120 cc. per gram of dry organic matter, calculated on the ether extractable matter in the fresh material, was obtained in 10 days.

(*c*) Fecal matter, that the digestion was nearly complete in four days, and the total volume of gas given off per gram of dry organic matter was 420 cc.

(2) In the experiments on the loss of nitrogen, 50-gram samples of a suitable mixture of thermophilic seeding and fresh sludge were put into two Kjeldahl flasks. The mixture in one of these flasks was acidified with sulphuric acid and the nitrogen content determined. The mixture in the second flask was digested at 53° C. over a period of two to three weeks. The gas from digestion was bubbled through ammonia-free water or dilute sulphuric acid during the process of collection. After completion of digestion the nitrogen content of the digested mixture and of the water or dilute sulphuric through which the gas had bubbled was determined. The analyses showed that:

(*a*) Very little if any free nitrogen is evolved during digestion at 50° to 55° C. In two experiments 97.72 and 96.50 per cent of the original nitrogen was found in the flasks after digestion.

(*b*) A small proportion of ammonia may pass away with the gas evolved during digestion. The percentages of the nitrogen recovered as ammonia were 1.87 and 1.36.

Experimental Sludge Digestion Plant

An experimental sludge-digestion plant, consisting of an open concrete receiving tank and two digestion tanks, was completed and put into commission in January, 1931. The mixed sludge receives a preliminary heating in the receiving tank before it is pumped to either of the digestion tanks. The digestion tanks are 15 ft. 6 inches deep, square in section with the lower half in the form of an inverted pyramid, and each has a capacity of 3222 gallons. The tanks are insulated with "Celotex" and are equipped with a hot water heating grill at about half depth. Heat is supplied by means of gas-fired tubular boiler. The digestion tanks are adjacent but are in no way connected and are operated at 25° to 30° C. and 50° to 55° C., respectively. To determine the drainability of the digested sludge, a series of twenty sludge drying beds each 16 by 16 ft. had been constructed.

The sludge digested has been a mixture of sedimentation tank sludge and activated sludge in the proportion of 6:1 on the basis of dry organic solids.

Digestion of Sludge at 25° to 30° C.—A well-digested sludge was used for seeding and a well-ripened active sludge was developed in a short time. The tank was first operated on a batch system and then slowly changed to a more continuous system of operation. The pH of the sludge varied from 8.0 to 8.5 and the gas production was 344 cc. per gram of dry organic matter in the fresh sludge added.

Thermophilic Digestion.—The tank was charged with a suitable sludge mixture and the temperature was slowly raised to 52° C. Fermenta-

tion did not become active until the tenth day. Following three months of operation on the batch system it was decided that the tank had not yet reached its maximum activity. The pH of the sludge varied from 8.0 to 9.0 and on the 8th filling the gas evolved in 6 days was equivalent to 684 cc. per gram of dry organic matter in the sludge.

The plant experiments have been controlled by corresponding laboratory trials. These laboratory experiments are useful in determining the economic point of recharging and in ascertaining the relation to total gas yielded when the fermentation is continued to completion to that obtained under the method of operating the plant. The experience with the plant has shown the digested sludge to be readily drainable.

Dagenham Sewage Works Extension Scheme

BY T. P. FRANCIS

The Surveyor, **80**, 503–505 (Nov. 20, 1931)

ABSTRACTED BY J. K. HOSKINS

The original sewage treatment works at Rainham, consisting of simple sedimentation for a flow of 1 Imp. m. g. d., were extended from time to time as required by the rapidly increasing population. The effluent, discharged into the Thames, has not met the recently adopted requirements of the Port of London Authority for about 3 p. p. m. of albuminoid ammonia. This, added to the increase in trades waste, has necessitated the provision of improved purification processes. The old works are to be retained in use with separate new plants for trades waste and for domestic sewage to serve the more recently developed industrial areas.

Old Rainham Works.—The screened sewage is pumped to cone bottom detritus tanks, passes into downward and upward flow chambers and then to four rectangular sedimentation tanks 100 by 30 ft. by $7\frac{1}{2}$ feet deep. The effluent is discharged to the Thames. The settled sludge is ejected through pipes for disposal on land where it is plowed in.

Extensions for Domestic Sewage.—This new plant is designed to treat 3 m. g. d. with an ultimate capacity of $4\frac{1}{2}$ m. g. d. The raw sewage will first pass through mechanical bar screens with $\frac{1}{2}$-inch openings and then into circular sedimentation tank providing 3 hours' detention. The clarified effluent will then be aerated in Simplex tanks for 4 hours and then settled for 3 hours in cone bottomed tanks. The activated sludge will be reaerated by diffused air in ridge-and-furrow tanks of 14 hours' capacity and a 25 per cent concentration of sludge. When the $4\frac{1}{2}$ m. g. d. is to be treated it is proposed to aerate for the first $1\frac{1}{2}$ hours with diffused air and then continue with mechanical aeration with an intermediate sedimenta-

tion period between, thereby providing a two-stage activated-sludge treatment.

Trade Waste Treatment.—The greater part of the trade waste is anticipated to be contributed by the Ford works, not yet completely developed. The nature of this waste being at present indeterminate, sedimentation only is provided, to be followed later by percolating filters if found necessary. The sludge, anticipated not to be digestible, is to be treated on under-drained sludge beds.

Sludge Treatment.—Land treatment of sludge having proved unsatisfactory and barging to sea non-practicable, designs have been prepared for heated digestion tanks using the developed gas for power. After consideration of various angles of the process it has been determined to construct a Dorr digester with a capacity of 1.33 cu. ft. per capita. If sufficient digestion is thereby provided the sludge will be dried in lagoons; if not, a portion of the lagoons will be converted into secondary digestion tanks by the construction of earthen banks. Such lagoons would function in a manner similar to the secondary tanks at Birmingham.

Costs.—The estimated cost of the scheme is £268,593.

Experiments on and Treatment for the Destruction of the Filter Fly (*Psychoda*)

BY W. D. SCOULLER, H. H. GOLDTHORPE AND W. WATSON

The Surveyor, **80**, 411–412 (October 30, 1931)

ABSTRACTED BY J. K. HOSKINS

Experiments for the control of the filter fly have been continued at Huddersfield, employing test filters consisting of glass cylinders with open ends partly filled with natural clinker. The outlet ends of the filters were trapped and the tops covered with muslin to prevent escape of the flies. The filters were operated for a month at a rate of 100 gallons of tank effluent per cubic yard per day until they were full of flies. The filters were then rested for 30 minutes, next treated with 0.5 per cent solution of the appropriate chemical for 10 minutes, again rested for 1 hour and then the usual filtration resumed. The effect of such disinfection on the flies was observed. The treatment was continued daily until no more flies appeared. Experiments using creosote oil with and without orthodichlorbenzene are described in detail.

The time taken to rid the filters of flies using 10 parts creosote and 1 part orthodichlorbenzene at the rate of 1 gallon per 175 square yards was 28 days and the time for flies to again reappear was 26 days. Employing creosote alone in the form of an emulsion and at the same rate required 41

days to eliminate the flies after which a dose every 5 or 6 days was enough to control them. A number of coal tar derivatives were tried and showed less effect than creosote. Paraffin oil in the quantities used had no effect.

Following these tests creosote with a tar acid content of 18 per cent by volume was employed in the full sized filters. The creosote oil emulsified with soap was added daily through the sprinkler system with the sewage for a period of 15 minutes. After 39 such treatments all flies had disappeared. A total of 20 additional intermittent treatments during the remainder of the summer period held the flies in check. The treatment had no appreciable effect on the filter effluent and entirely controlled aerial nuisance. The cost amounted to £53 11s 6d per acre per year.

The above paper presented at the annual general meeting of the Yorkshire District of the Association of Managers of Sewage Disposal Works brought out some interesting discussions. Mr. H. D. Bell of Barnsley had succeeded in reducing flies by chlorine and at the same time improved the filter effluent at a cost of 0.28d per sq. yd. per annum, in comparison with the 2.5d cost of creosote. Mr. H. Taylor experimenting with ammonia at Sheffield had reduced the flies without harm to filter efficiency. The value of the fly larvae in preventing ponding was discussed.

Sewage Disposal in a Mining District

ANON

The Surveyor, **80**, 365 (Oct. 16, 1931)

ABSTRACTED BY J. K. HOSKINS

The new sewage treatment works at Royston, Yorks, an urban district lying between Wakefield and Barnsley, serves a residential mining population of 7356 and replaces three separate overloaded installations. The plant is designed for an ultimate population of 8000 with a dry weather flow of 160,000 Imp. g. p. d. The present contribution is 13 gallons per capita daily.

The plant occupies a ten-acre tract, five acres of which are reserved for sludge disposal. After passing a detritus tank the sewage flows through two screening chambers with fixed bar screens with $^1/_2$ inch openings and an effective area of 50 sq. ft. Three rectangular sedimentation tanks with a total capacity of 80,000 gallons have bottoms sloping toward their inlets. Sludge plugs connect with the sludge pump well which also serves the detritus tank, screen chambers and two storm water tanks of a total capacity of 40,000 gallons.

The effluent from the sedimentation tanks flows over a weir to the dosing chamber, feeding the three circular sprinkling filters, each 90 feet in di-

ameter, by means of revolving distributors. The filtering medium is 3890 cu. yds. of vitrified clinker graded from 9 inches to $1^1/_2$ inches, equivalent to 45 gallons per cu. yd. of the dry weather flow. Final sedimentation is provided in two rectangular tanks with a total capacity of 40,000 gallons. The final effluent is discharged to a tributary of the river Dearne.

All sludge and detritus delivered to the sludge pump well is pumped to land by a specially designed 4-inch centrifugal pump, capable of raising 250 gallons of sewage per minute against a static head of 15.6 feet plus friction in 260 feet of 6-inch pipe.

The estimated cost of the scheme was £15,120, later somewhat reduced.

Survey of the River Tees. Part I. Hydrographical

BY H. T. CALVERT

Technical Paper No. **2**, Water Pollution Research, Department of Scientific and Industrial Research (Great Britain)

ABSTRACTED BY H. W. STREETER

In order to obtain more precise information concerning the self-purification of rivers receiving polluting effluents, a comprehensive scientific survey of the River Tees, a tidal stream flowing through an industrial area was undertaken. As the interpretation of the biological and chemical results involves a knowledge of the flow of fresh water of the upper river and of the movements of fresh and saline waters in the estuary, the investigation included hydrographical observations, particularly in the estuary.

The principal objects of the hydrographical survey were to obtain information on the tidal movements in the river and estuary with reference to: (1) strength and volume of currents over all ranges of tides and depths; (2) the general movement of water between Stockton, 12 miles from the mouth, and the sea; (3) the effect of fresh water floods on tidal movements in the estuary; (4) comparisons of water level at different states of tide; and (5) times and heights of high and low water throughout the estuary.

Fresh Water Observations.—Measurements of fresh water flow were made at Croft Bridge, 17 miles above the tidal limit, a water-level gage being established and read at this point twice daily beginning April 10, 1929. Flow gagings were made with floats over a distance of 100 yards and were checked by current meter observations. The latter indicated that the float readings were about 10 per cent too high. From measurements made between April and December, it was concluded that at normal summer level (1 ft.) the discharge is 100 mil. gals. daily; at normal winter level (1 ft. 9 in.), 287 m. g. d.; at high water level (2 ft. 6 in), 523 m. g. d. For

comparison, the average flow of the Thames at Teddington weir for 35 years is given as 2400 mil. gals daily.

Measurements in the Tidal Estuary.—Current meter measurements in the tidal estuary were made at ten stations between Stockton and Tees mouth. The results are presented in tables and in a series of diagrams consisting of: (1) curves showing the velocity of current at the surface and at 1-fathom intervals of depth, at various hours before and after high water, and (2) iso-pleths giving the same information in different form. These charts show clearly the relative velocities of flood and ebb flow at each station.

Movement of Water toward the Sea.—A study of the diagrams shows that the main force of the flood flows subsurface at 2 fathoms depth, whereas on the ebb the current flows fastest on the surface. This results from the natural tendency of the less dense fresh water from the upper river to remain in the surface layers and of the denser salt water to remain in the lower strata.

A preponderating down-river movement occurs only in the top layer, but the volume carried is greater than that moving upstream in all other layers. The difference was shown to be very nearly equal to the measured discharge of fresh water passing Croft Bridge.

Conclusion.—The most important fact brought out by the hydrographical survey is that at some points there are considerable differences between the surface and deeper waters, and that at certain times the flood runs upstream below the surface while the ebb still runs on the surface. The conclusion may be drawn that polluting matter cannot escape seawards easily unless it is in the surface layer. This is important in considering the discharge of effluents.

The survey has shown that float measurements are not suitable for a tidal estuary, where the water is stratified and a float might take many days to reach the sea even if not caught in an eddy.

Observations at one station show that at this point, at least, the velocity of the whole cross section can be approximated by multiplying the center-line velocity by 0.8. It is doubtful whether such a factor has any real meaning in an estuary, except with respect to the average of a large number of observations.

In future surveys of an estuary, attention should be paid to obtaining accurate measuremets of the thickness of the upper layer. Closely spaced coincident observations of temperature and salinity would permit density sections to be drawn, while the salinities alone would make it possible to calculate the volume of water moving in the two layers by the theorem of Prof. Knudsen.

The report is well illustrated and contains an excellent preface by Dr. H. T. Calvert, Director of Water Pollution Research.

Wards Island Sewage Treatment Plant Begun

BY GEORGE W. FULLER

Civil Engineering, **1**, 14, 1260–1265 (November, 1931)

ABSTRACTED BY H. W. STREETER

On July 7, 1931, ground was broken at New York for the construction of the Wards Island plant, which will be the largest activated sludge sewage disposal works in the world. It will treat a flow of 180 m. g. d. of sewage and serve a population of 1,350,000, nearly $^1/_5$ of that of Greater New York. This $30,000,000 plant, with its collecting works, is the first part of a program calling for the ultimate treatment of all sewage entering New York harbor, approaching in volume $1^1/_2$ billion gallons daily. This plant will serve a total area of 7420 acres, including 2720 acres in Manhattan now draining into the East and Harlem Rivers, and 4700 acres in the Bronx.

Interceptors and Appurtenances.—Along the East and Harlem Rivers water fronts, interceptors will be provided for 54 sewers in Manhattan and 20 in the Bronx. They will be equipped with regulating devices for diverting the dry-weather flow and the first flush of storm flows from the existing outlet sewers. Tidal gates will prevent river water from flooding the interceptors at high tide.

The intercepted sewage will flow by gravity to two low points at which grit chambers and screens will be installed. From each grit chamber separate tunnels, in solid rock and about 300 ft. below the surface, will lead to the Wards Island works. The tunnels will terminate in uptake shafts from which the pumps will lift the sewage 46 ft., discharging it through conduits into the preliminary settling tanks.

Treatment Works.—The treatment works proper will consist of preliminary sedimentation tanks, aeration tanks for activated sludge treatment, final settling tanks, return and excess sludge pumps, sludge storage tanks, and operating galleries, meters, gates and various structures for housing the plant. In addition there will be a dock for loading sludge boats, a central heating plant, an administration building with offices and control laboratory, and a fertilizer plant for demonstration purposes.

After preliminary sedimentation, the settled sewage will flow to the aeration tanks through conduits equipped with Venturi meters. The return activated sludge will be added just before the sewage reaches the aeration tanks. The effluent of these tanks will flow across the operating galleries to the final settling tanks. Here the clear liquid will be drawn off the top and discharged to the East River. The volume of activated sludge returned to the inlet conduits of the aeration tanks will be equivalent to some 25 per cent of the raw sewage. The rest will go to the sludge storage tanks at the dock, for loading into sludge boats after decantation.

In order to provide for storm flows in excess of $1^1/_2$ times the 180 m. g. d. dry-weather influx, overflow weirs are provided in the effluent conduits of the preliminary tanks. After clarification, the excess effluent passes over these weirs and through a conduit having a submerged outlet into the East River.

The experimental fertilizer plant will have a capacity of 15–20 tons daily. It is equivalent to one drier unit, including storage for the finished product, and is laid out advantageously for future extension. In this plant sludge from the final settling tanks will be conditioned by addition of chemicals, filtered through vacuum filters, dried in oil-fired driers and then screened and disintegrated. The cost of the treatment works, as estimated in 1929, was $18,000,000 and of the interceptors and tunnels $12,000,000. It is estimated that $4^1/_2$ years will be required for completion of the project.

Mechanical Aeration for Domestic Sewage

BY CHARLES W. DARE AND WILLIAM E. COLLINGS

The American City, **XLV**, No. 5, pp. 88–90 (Nov., 1931)

ABSTRACTED BY E. HURWITZ

The Collingswood, N. J., sewage treatment plant serves a population of 13,000 and receives an average of 0.8 m. g. sewage per day.

Sewage enters the plant through a small grit chamber. It then flows to the preliminary settling tanks which have a detention period of about one hour. These tanks are 14.5 ft. wide by 45 ft. long by 8.5 ft. deep and are equipped with Link Belt straight line collectors. From the preliminary settlers the sewage flows to the aerating units through a distributing box. The aerating tanks, of which there are four, are 125 ft. long by 13.5 feet wide by 8.5 feet deep and are provided with Link Belt mechanical aerators. The effluent from the aerators flows into final settling tanks 14.5 feet by 43.5 feet by 6.5 feet deep, also equipped with Link Belt collectors. The effluent from these tanks flows into a mixing tank where it is chlorinated and thence through a contact chamber into the outfall sewer.

The sludge from the preliminary settlers and the excess sludge from the final settlers flows by gravity into a separate sludge digesting tank. The tank is divided into two compartments and has a total capacity of 43,000 cu. ft. Provision is made for liming and for circulating the sludge. The gas is collected and used for heating the tank.

The digested sludge is dried on eight drying beds, six of which are glass covered. The efficiency of the plant is indicated by the reduction in B. O. D. in the units of the plant as typified by the analyses of May 1, 1931: Influent, 795; Preliminary settler effluent, 670; Final effluent, 7.7.

See also THIS JOURNAL, **3**, 636, (October, 1931).

Odor Control in a Small Town Disposal Plant

BY H. G. OLMSTED

The American City, **XLV**, No. 5, pp. 69–70 (Nov., 1931)

ABSTRACTED BY E. HURWITZ

The location of the sewage disposal plant adjacent the city hospital at Farmington, New Mexico, made the control of odors of utmost importance.

The plant consists of an Imhoff tank, dosing tank, sprinkling filter, sludge drying bed and chlorinator. The scum and gas chambers of the Imhoff tank are fitted with air-tight concrete covers provided with manholes which are also tightly sealed. A shaft carrying paddles runs the full length of the tank and serves as a means of breaking up the scum, thus preventing it from compacting. The gas is collected in a small gas storage tank from whence it is piped to a gas burner. The filter effluent is chlorinated using chloride of lime as the chlorinating medium. The entire plant with the exception of the sludge drying beds is under cover, thus practically precluding the escape of odors. It is planned to cover the drying beds at a later date.

Sewerage and Sewage Disposal at Freeport, N. Y.

BY L. L. LUTHER

The American City, **XLV**, No. 6 (Dec., 1931)

ABSTRACTED BY E. HURWITZ

The village of Freeport has a total of 38.5 miles of sanitary sewers and a modern treatment works and pumping station. The sewerage system was designed to care for a contributory population of 42,000 people with a maximum flow of 250 gal. per capita per day. The present population of Freeport is only 19,475 and the water consumption 68 gal. per capita. It is estimated that the trunk sewer will be sufficiently large for at least 20 years.

The pumping station is provided with three pumps, automatically operated, and arranged so that the pumps cut in in succession as the height of the sewage in the suction well rises.

On reaching the treatment works the sewage passes through covered settling tanks with a capacity sufficient to provide four hours settling with 5 per cent additional space for storage of sludge. The effluent flows out of the settling tanks into the chlorinating chamber and after approximately a 30-minute detention period passes into the outfall sewer and thence into Freeport Creek.

The sludge is pumped from the settling tanks into digestion tanks sufficiently large to provide a digestion period of 150 days based on 2.3 cu. feet per capita per day. These tanks are covered with a concrete roof.

The digested sludge is removed by gravity to glass covered sludge-drying beds having a total area of approximately 5000 sq. ft. or about $1^1/_2$ sq. ft. per capita. The sludge liquor is decanted and returned to the settling tanks.

The plan of the buildings and superstructures is such as to give a pleasing impression. No odors or noises eminate from the plant and in general the effect on the senses of the populace is satisfactory.

Data on plant operation is given below:

Type of sewage	Fresh domestic
Flow	500,000 g. p. d.
Population served	2200
Cl_2 applied	43.3 pounds per m. g.
Power consumed per m. g.	63.35 kw.
Cost per m. g.	$12.00
Average residual Cl_2	0.4 p. p. m.
Average solids removed (2 hour settling in Imhoff Cone)	97.3 per cent
Average pH of influent	6.4
Average pH of effluent	6.8
Average pH of digestion tanks	7.1
Average moisture of sludge as drawn	86.4 per cent
Average solid matter in sludge	13.6 per cent
Relative stability of tank effluent (methylene blue)	48 per cent

Treatment of Moscow's Sewage

BY S. STROGANOV

Municipal Sanitation, **2**, 574–577 (Dec., 1931)

ABSTRACTED BY E. HURWITZ

The Kozhukhova aeration plant is located on the Moskva River, just outside of Moscow. At this plant experimentation, with a view toward building a plant to treat all the sewage of Moscow, is being carried on. The plant is designed to treat about 3.5 m. g. d. but at present is handling only 30 per cent of this flow.

The units of the plant consist of coarse screens, hand cleaned; primary settlers having a one-hour period; the aeration tanks or "coagulators" in which an aeration period of 30 minutes to one hour is maintained dependent on the quality of the return sludge and properties of the incoming sewage; and secondary settling tanks. From the secondary settling tanks the efflu-

ent received further treatment in the "aerofilters," which are slag filters with grated bottoms through which air is pumped. The sludge is pumped to "regenerators" where it receives further aeration. Eight to ten per cent of the sludge is returned to the aeration tanks, the excess sludge will be wasted to the "methane" or digeston tanks when these are completed.

The last step in the purification process is the "pond" in which the effluent from the aerofilters is subjected to the influence of natural agents such as light, heat, etc. It is expected that this final treatment will materially reduce the number of bacteria remaining in the effluent, consequently giving this stage of treatment great significance, especially in summer when the Moskva River, into which the effluent empties, is widely used. Provision is made for chlorination of the sewage in emergencies.

The article abstracted above is a translation from the Russian publication *Kommunalnoye Khosyaystov.*

Acid Sludge Digestion

BY E. L. PEARSON AND A. M. BUSWELL

Ind. Eng. Chem., **23**, 1144–1145 (1931)

ABSTRACTED BY P. D. MCNAMEE

Fresh solids from a nidus tank, which was fed with a mixture of sewage and creek water, caused an acid reaction when fed into a digestion tank containing domestic sewage. The addition of lime on the sixtieth day and of actively digesting sludge on the seventieth day failed to bring about normal digestion. In this experiment, the fresh solids differed from the fresh solids fed in previous experiments (where normal digestion occurred) in that the grease and protein values were relatively low and the undetermined fraction quite high. The undetermined fraction probably contained considerable humuslike material owing to the presence of creek water in the nidus tank from which the fresh solids were obtained.

The extent of sludge digestion was measured by determining the amount of total solids, volatile matter, ash, grease, protein, crude fiber, ammonia and acetic acid, entering and leaving the digestion system as well as the amount of gas produced. It was found that the decomposition of the grease was retarded to a greater extent than was the decomposition of the proteins; 47.2 per cent of the grease and 46.1 per cent of the protein being decomposed compared to 90.3 per cent of the grease and 63.5 per cent of the protein in a previous alkaline-digestion experiment.

The authors believe that the acid condition was caused by the chance development of the wrong bacterial flora and not by a chemical poison.

Sludge Ripeness Studies

BY E. L. PEARSON AND A. M. BUSWELL

Ind. Eng. Chem., Anal. Ed., **3**, 359 (1931)

ABSTRACTED BY P. D. MCNAMEE

Tests employed in determining the ripeness of sludge were studied. The following tentative conclusions are drawn:

The draining quality of a digested sludge is roughly inversely related to its ripeness and to the ease with which the non-draining moisture is moved.

In the continuous feed process of sludge digestion, volatile acids are a better index of the course of digestion than of its degree of completion.

The ash and solids content of a digested sludge may be satisfactory locally as an indication of ripeness, but both are also dependent on other factors, and are, therefore, not of general applicability.

Most of the sludges from the experimental plant had a biochemical oxygen demand below 1500 p. p. m. but were not considered sufficiently ripened to permit ready disposal.

Correlation of the rate of gas production under standard conditions with the ripeness of a digested sludge is being attempted.

Lime-Chlorine Treatment at Dayton, Ohio

BY M. W. TATLOCK

Water Works and Sewerage, **78**, 347 (1931)

ABSTRACTED BY G. P. EDWARDS

The Dayton sewage treatment plant, which provides primary treatment only, consists of circular detritus tanks equipped with Dorr Clarifiers, Imhoff tanks with gas collection and glass-covered sludge beds. The bottom concentrate from the detritus tanks passes through grit channels equipped with Link Belt continuous-flight grit removers and then through Dorr screens. The plant was placed in operation in November, 1929. During the summer of 1930, some complaints of odors were reported. Lime-chlorine treatment was installed. In this treatment, as developed by Linn Enslow, a mixture of chlorine solution and milk of lime is added to the sewage. A dosage of 11 p. p. m. chlorine for an average flow of 23.75 million gallons per day was quite satisfactory, not only eliminating odors but improving general plant operation. The skimmings on the detritus tanks have been reduced from 0.51 to 0.35 cu. ft. per million gallons or 31 per cent. On the Imhoff tanks they have been reduced from 2.10 to 1.27 cu. ft. per million gallons or 39.5 per cent. The reduction in

the amount of scum removed from the Imhoff tanks adds 16.5 per cent to the drying capacity of the present sludge beds. Since this procedure has been adopted there has been a 17 per cent increase in biochemical oxygen demand reduction. The tanks have been able to treat a heavier load with the same per cent suspended solid removal and there is a saving of 22 per cent per million gallons sewage due to decreased labor. The cost per day of lime-chlorine treatment is $2.19 per million gallons.

Sludge Gas Explosion at Sewage Works, Woonsocket, Rhode Island

Water Works and Sewerage, **78**, 284 (1931)

ABSTRACTED BY G. P. EDWARDS

On October 2, 1931, at 11:25 A.M. an explosion of two sludge digestion tanks at the Sewage Treatment Works of Woonsocket, R. I., blew off the roof and killed two workmen. The exact cause of gas ignition and explosion has not been determined. The tank which exploded had been partially emptied incident to transfer of sludge to an adjoining tank for seeding. The manholes in the roof had been opened and one man was standing on a rung of an iron or steel ladder in the tank making an inspection. The other man who had just emerged was standing on the roof of the tank. The man in the tank was not using any tools. There was still about 3 ft. of partly digested sludge in the tank and all metal work was reported to be wet at the time. Gas burning had been discontinued before the inspection and explosion. The soles of the shoes worn by the man in the tank were of rubber composition. The explosion was probably due to thoughtlessness on the workman's part as he must have struck a light while in the tank.

Milk Products Waste Treatment Report No. 3

BY E. F. ELDRIDGE

Michigan Eng. Expt. Station, *Bull.* **35** (Apr., 1931)

ABSTRACTED BY H. W. STREETER

In two previous reports (*Bulletins* 24 and 28) the results obtained from chemical precipitation and from the use of sand, gravel, cinder and brush filters in the treatment of milk waste have been described. The present report contains the results of pre-aeration experiments, of the further operation of the biological filter and a study of the treatment of cheese whey solutions. These are followed by some suggestions on the design, construc-

tion and operation of large scale filters. The latter part of the report is devoted to the results of a study of the treatment of combined sanitary sewage and milk waste.

Preaeration Studies.—Two series of experiments were undertaken, both dealing with the waste from the college dairy. First were observations on aeration of the waste for periods up to 4 hours, in which the maximum dissolved oxygen content was attained after one hour, followed by a progressive decline. When the waste was applied to a gravel filter (10 ft. diameter and 10 ft. deep) after one hour of aeration, a slight improvement in B. O. D. removal was noted, as compared with that of the same filter without preaeration. This slight advantage is not considered sufficient to justify the extra cost of short preaeration on a plant scale.

The second series of observations was based on 8 hours' aeration of the waste in the presence of an activated sludge developed from this treatment. After trial, the best results were obtained with 4 per cent of sludge by volume in the aeration tank. The reduction in B. O. D. ranged up to 65 per cent, but averaged much lower with a raw waste B. O. D. varying from 460 to 1900 p. p. m. The sludge from the process was difficult to handle, having a high water content and foul odor. It cannot be dried on an ordinary sludge bed, but must be incinerated. Filtration of the effluent is possible but the waste must be settled to avoid clogging up the filter. The odors and fly nuisance, together with the sludge problem and low efficiency, lead to the conclusion that this method does not compare in efficiency, simplicity or economy with biological filtration when applied to milk products waste.

Biological Filtration of Whey Solutions.—Whey, from the manufacture of cheese, should be considered as a by-product rather than as a waste. It contains 4 to 4.5 per cent milk sugar and other products making it valuable for feeding, if not for milk-sugar manufacture. Many small plants, however, cannot be economically equipped for recovering sugar and have no outlet for whey for feeding; hence provision must be made for its treatment.

Wastes from a cheese factory contain a considerable amount of whey. The effect of this large proportion of whey on the operation of the biological filter was not known. Experiments were undertaken to determine this effect and if possible extend the use of the filter to cheese factory wastes.

The filter, built up with fresh milk waste, was operated on whey solutions for about one month, the rate of application being 1.0 m. g. d. and the filter being operated 8–10 hrs. daily. With solutions containing 3.3 to 10 per cent of whey, and having a B. O. D. ranging from 800 to 3600 p. p m., excellent reductions in B. O. D. were obtained, the maximum being as high as 97 per cent after pasing filter depths of 8–10 feet. The pH of the whey

solution is a limiting factor, being 6.4 with a 10 per cent concentration of whey. Strengths greater than this are not recommended.

The conclusions drawn are:

(1) Whey can be treated on a biological filter if built up with fresh milk previously, or provided that fresh milk waste be mixed with the whey during treatment. The latter is preferable.

(2) Solutions of as high as 10 per cent of whey can be successfully oxidized on the filter when applied at the rate of 1.0 m. g. d. and for a period not exceeding 8 to 10 hours daily.

(3) Cheese factories can use the filter for treatment of cheese washings along with other plant wastes, provided that the strength of the waste does not exceed that of a 10 per cent solution of whey.

General Summary of Treatment Studies.—(1) Septic tanks and other bacterial devices cannot be used successfully for treatment of milk products waste.

(2) Broad irrigation may be used where land is available and where nuisance will not be produced by odors.

(3) Chemical precipitation with lime and copperas will remove a portion of the milk solids if properly controlled, but is not recommended as a general method because of relative inefficiency and cost of construction and operation.

(4) Activated sludge, if properly controlled, will remove about 65 per cent of the milk solids, but because of high cost, odors, difficult operation and relative inefficiency, is not recommended for milk wastes.

(5) Biological filtration over gravel, crushed stone or slag provides an efficient, relatively economical and simple method of milk wastes treatment, if a few simple rules are followed, viz.:

(*a*) The filter should be at least 7 feet deep.

(*b*) It should be composed of stones graded in size from $1^1/_2$ to $3^1/_2$ inches.

(*c*) The waste should be applied at a rate not exceeding 1.0 mil. gals. per 24-hour day.

(*d*) The filter should not be operated for more than 10 to 12 hours daily.

(*e*) The strength of waste applied should not exceed a B. O. D. of 1600 p. p. m. if an ordinary milk waste. Wastes higher in carbohydrates, such as whey, can be much stronger, as material of this type is handled more rapidly than fat or protein.

(*f*) The filter should be operated daily with the possible exception of Sunday.

(6) Preaeration of the waste before filtration does not give sufficient advantage to warrant the cost of equipment.

(7) Whey solutions up to 10 per cent in strength can be treated on the biological filter under the conditions above stated.

In addition, the bulletin contains some valuable suggestions on the construction and operation of the biological filter and other equipment useful for the treatment of milk products waste; also a discussion of experiments made on the treatment of combined sewage and milk waste at Mason, Michigan. The text is well illustrated.

The Effect of the Disposal of Water Softening Plant Sludge through the Sewage Disposal Plant

BY E. F. ELDRIDGE

Michigan Eng. Expt. Station, *Bull.* **34,** (Jan., 1931)

ABSTRACTED BY H. W. STREETER

Water softening plants using the lime or lime-soda process produce a large quantity of sludge. Disposal of this sludge is becoming a more difficult problem as the demand for softened water increases. Objections have been raised to the prevailing custom of discharging this sludge into streams used for water supplies and the day is not far distant when some other method of disposal must be adopted. The work contemplated, of which this is a preliminary report, has as its object the disposal of softening plant sludge through the medium of the sewage disposal plant.

The content of the sludge, though varying from plant to plant, will consist largely of calcium carbonate when lime alone is used, and of calcium carbonate and magnesium hydrate, with a higher causticity, when the lime-soda process is followed. The quantity of the sludge, as measured by dry solids, depends on the type of treatment and the hardness of the original water. For every p. p. m. of hardness removed, 0.74 p. p. m. $Ca(OH)_2$, or 0.56 p. p. m. CaO is required and 2 p. p. m. of $CaCO_3$ is obtained as sludge. The amount of material obtained is exemplified at one plant in Michigan, at which the average and maximum volumes of water treated are 18 and 25 mil. gals. daily, respectively. To obtain the degree of softening required, 1000 lbs. of CaO are added per mil. gals. and the average weight of dried solids in the sludge of this plant amounts to about 32 tons per day. The effect of discharging such a large volume of this sludge into a stream is obvious. Although the calcium carbonate is inert, the stream bed is soon covered to a considerable depth with sludge, particularly in the low water period.

Other methods of disposing of this sludge have not been very successful. It cannot be air-dried and only with difficulty is separated by mechanical filters. The calcium carbonate obtained is practically useless, as the cost of converting it to calcium oxide is greater than the cost of new lime.

Sludge disposal facilities are always provided at sewage plants but never at water softening plants. Knowing the value of acidity control in the digestion of sewage solids, it was thought that utilization of water softening sludge in this connection might serve both this purpose and the disposal of the sludge.

The major work will be done at the Grand Rapids sewage disposal plant using the lime sludge produced at the water softening plant at that place. The softening plant sludge will be admitted to the sewerage system at a point about three miles from the treatment plant. The quantity of sludge admitted will be controlled and increased as the studies progress. The main factors to be determined are as follows:

1. The effect on the pH of the effluent from the sewage settling tanks.
2. The effect on the settling rate.
3. The increase in sludge quantity, requiring an increase in sludge capacity.
4. The effect on digestion of the sewage sludge.
5. The effect on the drying and disposal of the sludge after digestion.

The laboratory studies thus far made on this problem have been confined to the effect of varying amounts of lime sludge on the digestion of sewage solids. The former material was obtained from the Grand Rapids softening plant and the latter from the Imhoff tank at East Lansing. Twelve 1500 cc. samples of Imhoff tank sludge were placed in individual bottles and each connected to inverted glass cylinders for gas collection and measurement. Nos. 1 and 2 were left with no lime sludge added; Nos. 3 and 4 were treated with 25 per cent of lime sludge, by dry weight; Nos. 5 and 6, with 50 per cent; Nos. 7 and 8, with 75 per cent; Nos. 9 and 10, with 100 per cent, and Nos. 11 and 12, with 150 per cent. All were mixed and connected to the gas collectors. Gas production in Nos. 1 to 6 (control, 25 per cent and 50 per cent lime sludge) started immediately; with the 75 per cent lime, after three days; with the 100 per cent lime, after 6 days; and with the 150 per cent lime, after 18 days. Digestion of the control samples (Nos. 1 and 2) were completed in 20 days and of the 25 per cent lime mixtures in 17 days, though the starting of digestion was delayed. More gas was obtained from the 25 per cent and 50 per cent samples than from the control, and the greater volume of gas was obtained from the 50 per cent lime mixture. With the 75 per cent mixture, the rate of digestion was considerably depressed, though the volume of gas finally resulting was about the same. The 100 per cent samples were further depressed. With the 150 per cent lime sludge, digestion did not start until after 18 days and only a small amount of gas was produced after 43 days.

These results show that there is a limit to the amount of lime sludge which can be mixed with sewage sludge in the disposal plant. From these studies it is believed that the optimum pH for sludge digestion is 7.2 to 7.6.

Rural Water Supply and Sewage Disposal Systems

BY C. A. HOLMQUIST AND EARL DEVENDORF

Bulletin, Division of Sanitation, New York State Department of Health (November, 1931)

ABSTRACTED BY C. C. RUCHHOFT

In arranging for sewage disposal upon the watershed of any public water supply permits are required and the Department should be consulted. Arrangements not on public water supply water sheds designed to serve less than 25 persons do not require permits.

Considerations of convenience usually determine the method of disposal to be employed. Where running water is available modern flush toilets connected with a sewer system is the most desirable arrangement. In this case the treatment device may be a septic tank connected to a subsurface tile system or to covered sand filters. A leaching cesspool may also be used where soil conditions are good. Various local conditions which are discussed will determine the plant most suitable for each case. Directions for the construction of all of these units with diagrams of details are given.

Where necessity prevents the installation of flush toilets safe arrangements are necessary for disposal or storage of the wastes at the place of deposition. In this case a pit privy, concrete vault privy, commercial chemical toilet or removable receptacle privy may be used. The concrete vault privy or commercial chemical privy is advocated when the nearby ground water must be protected from pollution. The removable receptacle privy has many disadvantages and its use is not encouraged. Instructions for locating, constructing and maintaining the various privies are given.

Digestion of Sludge from Strawboard Waste with Sewage Sludge

BY E. F. ELDRIDGE AND W. L. MALLMAN

Michigan Eng. Expt. Sta., *Bull.* **39**, 11–14 (July, 1931)

ABSTRACTED BY H. W. STREETER

Many methods have been attempted for disposing of strawboard wastes, which have caused serious stream pollution, with damage suits against strawboard companies. At some plants large settling ponds have been used; in others, vacuum filters for removal of suspended matters. Attempts now being made to treat the waste along with city sewage have led to these laboratory experiments to determine the effect of mixing sewage sludge in varying proportions on the rate of digestion of the straw waste.

The straw waste comes principally from the beaters, in which the straw is beaten to a pulp, and the paper machines on which it is made into paper. The average amount of suspended matter in the beater waste is 6000 p. p. m. and in the machine waste 800 p. p. m. After mixture, the suspended solids in the composite waste average 2300 p. p. m. About 75 per cent of this material can be settled in 1 to 1.5 hours. Based on the rated volume of 30,000 gals. per ton of product, the weight of sludge produced would be 420 lbs., averaging 85 per cent volatile matter (365 lbs. per ton of paper produced).

Strawboard waste was concentrated by decantation to 10 gms. of solids per liter. The sewage sludge, taken from an Imhoff tank, was partly digested and had a volatile content of 59.4 per cent. Four mixtures were prepared, ranging from 2 parts sewage: 1 part straw, to 1 part sewage: 3 parts straw. These, together with samples of each unmixed component, were digested at 72° F. in 3-liter bottles, connected to inverted glass cylinders for gas collection, and the amounts of gas thus collected were measured each day. After 89 days, gasification had practically ceased in all the samples.

Results.—Very little loss in volatile matter occurred in the unseeded straw sludge, but in all of the mixtures, as well as in the sewage sludge, 50–54 per cent of volatile matter was lost. With the exception of the sewage sludge alone, the gas produced per gram of solids added was highest in the 1 to 1 mixture. The rate of digestion was highest for the sewage sludge alone and diminished with increased proportions of straw waste in the mixtures. From both standpoints, the 1 to 1 mixture appears to be the optimum.

Fourth Annual Report, Ohio Conference on Sewage Treatment, Oct. 16–17, 1930

Publication of the State Department of Health, Columbus, Ohio

ABSTRACTED BY E. HURWITZ

The Dayton Sewage Treatment Works. By M. W. TATLOCK. Pp. 10–29.—The Dayton plant is located on the west bank of the Miami River, three and one-half miles from the center of town on a 500-acre tract. The cost, including land purchase, main interceptor, pumping station and treatment works proper totaled approximately $2,000,000.

Sewage is brought to the plant by six pumps of the vertical-shaft type with direct-connected motor, having a total capacity of 61 m. g. d. It flows through two 40-ft. clarifier tanks where grease is skimmed off by hand and removed to a dump pit for burial. The grit and coarser solids

are concentrated by Dorr clarifying mechanisms and pumped to the grit chamber where the heavier solids settle out and the lighter organic matter continues on to the fine screens. The detention period in these grit chambers is regulated by adjustable weirs and ranges from 0.7 to 1.3 ft. per sec. at 3.2 m. g. d. flow. The grit is removed by Link-Belt flight conveyors.

From the grit chamber the sewage flows through two 4 by 6 ft. Dorr drum screens provided with $^1/_8$-in. by 2-in. slots. Screenings are pressed to a moisture content of about 63 per cent and burned in a gas fired incinerator at 1600° F.

The sewage flows from the screens to six Imhoff tanks, each 88 ft. by 73 ft. 9 in., arranged in two batteries of three tanks each. Provision is made for the collection and use of the gas produced in these tanks and for circulating of sludge from one tank to another.

The digested sludge is dried on covered beds having an area of 2.43 acres. A table of operating data for the first 8 months is included.

Experiences with Industrial Wastes at the Fostoria Sewage Treatment Plant. By A. B. CAMERON. Pp. 30–117.—The original plant at Fostoria, built in 1896, consisted of two 100 ft. by 30 ft. by 9 ft. deep septic tanks and six sand filters having an area of 5.6 acres. In 1914 the plant was revamped into an Imhoff-sand filter unit. In 1923 the plant was again found to be inadequate and changes were made which enabled the plant to function, after a fashion, until the fall of 1927. At this time two compartments of the Imhoff tank became clogged and the sand filter lost its usefulness. It was then decided to make a careful study of conditions affecting the treatment of Fostoria sewage. This study resulted in the recommendation of treatment consisting of primary sedimentation followed by trickling filters with secondary settling. The sludge from the clarifying units was to be digested in separate digesters and dried on sand beds.

This plant was put into operation in March, 1928. In October of the same year it was shut down for repairs made necessary by the presence in the sewage of excessive amounts of acid iron waste from the pickling vats of the steel works and carbon dust wastes from other industries. These wastes caused the digestion tank to become completely filled in the eight months of operation and clogged the filter beds to such an extent that the degree of purification effected in the last week before shutting down was practically negligible.

It was deemed necessary to remove these wastes from the sewage system and, by coöperation between the industries responsible and the city, this was accomplished. The plant was then rehabilitated and improved and results obtained in 1930 show satisfactory operation.

The report contains a lengthy account of the litigation brought by riparian owners in which the city was involved.

Some Observed Effects of Dilution in the Self-Purification of Streams. By J. K. HOSKINS. Pp. 118–130.—Experimental work at the U. S. Public Health Service indicates that the oxidation process which results in the purification of polluted water takes place during the stage of active multiplication of bacterial cells and if for any reason this growth is retarded or stimulated the rate of oxidation responds accordingly. The governing factor in this oxidation is the *rate* at which the cells multiply, not the number of cells. It has also been shown that in cultures of bacteria only, the bacterial population reaches a condition of maximum density in a short time, after which very little further multiplication takes place. Under such conditions oxidation of organic matter ceases.

This condition is prevented in nature by the presence of bacteria-eating plankton. A biological balance is established; the bacteria on the one hand multiplying rapidly at the expense of the organic matter and their numbers being constantly reduced on the other hand by plankton. As the food supply diminishes the bacterial growth is retarded, the plankton numbers decrease and as a result a water becomes increasingly free from organic pollution, bacteria and plankton. It becomes naturally purified.

The effects of dilution on this balance were observed in the laboratory and under actual stream conditions. Indications are that the rate at which bacteria multiply varies directly as the degree of dilution; also that the bacterial density is increased following dilution. The reason advanced for this is that reduction of the density of bacteria below their limiting number and reduction in the number of plankton by dilution offers a condition favorable to the multiplication of the bacterial cells. Inasmuch as the generation time of protozoa is considerably greater than of bacteria, the bacteria would have an opportunity to increase extensively before a biological balance could be re-established.

The observations discussed were made on the Illinois and Ohio Rivers and their tributaries.

The Relation between Design and Operation of Sewage Treatment Works. By ROBERT A. ALLTON. Pp. 131–134.—The design of a sewage plant should be such as to facilitate operation in all ways possible. The designer should lay out the plant so that it will have flexibility of operation and easy accessibility to all its parts. Simplicity and compactness are essentials. He may be aided in formulating his design by cooperation with the plant operator, who should have available the information for the proper design to meet the conditions of his plant.

Some Observations on the Design and Operation of Sewage Treatment Plants for Country Clubs and Private Estates. By R. F. MACDOWELL. Pp. 144–158.—Observations made on plants having three types of secondary treatment, namely lath filters, sub-surface intermittent sand filters, and subsoil absorption, indicate that with proper supervision

satisfactory results may be obtained from lath filter plants. Such plants are not costly, they require little space, all parts are accessible and the sewage is not exposed.

The subsurface filters give very good effluents but must be of generous design if long life of the filter is to be expected. Subsoil absorption is applicable only where sewage flow is small and soil porous. Impervious soils require special construction.

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ABSTRACTED BY H. GLADYS SWOPE

The papers published in this report were presented October 23–25, 1930, before the Missouri Water and Sewerage Conference at Columbia, Missouri. There are twelve papers dealing with water problems and four on sewage problems. An abstract of each of the latter follows.

Sewage Pumping Stations. By C. KELSEY MATHEWS.—There are four general conditions which make a sewage pumping station necessary. First, it may be economical to pump sewage from a gravity main, prior to reaching the point of final discharge, to a higher elevation from which a gravity force main may be designed to continue to the point of final disposal. Second, loss of head through a treatment plant may necessitate pumpage. Third, the elevation of the outlet of a gravity sewer may frequently be submerged by high water. Fourth, it may be more economical to pump sewage from one collecting system to another rather than to install two or more treatment plants.

Three principal requirements should be considered for the proper design and operation of a sewage pumping station. First, the capacity must provide for the maximum rate of flow so as not to force contributing sewers to flow under pressure. Second, septic action must be retarded. This may be accomplished by limiting the storage space, draining the wet well of all settleable solids each time the pumps discharge and as a further precaution, chlorination at the inlet to the sump. Third, the pumping station should be automatically controlled.

Sewage pumps are discussed and the author has divided these into three general types: centrifugal, screw pumps and ejectors. Centrifugal pumps are generally used for pumping sewage at rates of 250 to 50,000 g. p. m. against total heads of 8 to 70 feet. Screw pumps are used for low heads and are generally used for rates between 1000 and 300,000 g. p. m. for heads ranging from 3 or 4 feet to 25 feet. Ejectors are used for smaller stations where rates are from 50 to 500 g. p. m. at a head range up to 50 feet.

Causes and Prevention of Foaming in Imhoff Tanks. By GEORGE S. RUSSELL.—Foaming seems to be caused primarily when the sludge becomes acid. It is therefore important that there be quick contact of the new sludge entering the digestion chamber through the slot in the sedimentation compartment with the old ripened sludge, as hours of delay at this state are equivalent to days as far as the retardation of the digestion process is concerned.

The author believes that rising gas-filled scum requires a certain minimum of surface area in order to release its gas and that this area is not sufficient in the ordinary types of Imhoff tanks.

The first condition, acid digestion, can be corrected by the addition of lime. This is generally necessary when a tank is first put into operation or started up after a shut-down for repairs. When the tank has been in operation for some time some method of reducing the flow of gas or mixing the contents is necessary so that alkaline ripened sludge may be brought into contact with the newer sludge.

In Germany, a new type of tank has been developed which has a submerged sedimentation compartment. This type increases the scum area and makes the release of gas easier by bringing the level of the sewage in the digestion chamber above the top of the sedimentation compartment.

The Activated Sludge Process in Small Installations. By F. M. VEATCH.—The paper is a general discussion of the activated-sludge process. If complete treatment is necessary, even in the case of small plants, the activated-sludge process has distinct advantages over other existing types. The author has compared this process with sand and sprinkling filters from the standpoint of quality of the effluent, construction and operating cost, area required, head required, freedom from odors and resistance to heavy loads. The activated-sludge process was found to be the most desirable based on these criteria. There is one great disadvantage. Certain types of industrial wastes interfere with this type of treatment. Such wastes may, however, be treated separately or be fed to the plant at a low, continuous rate.

A discussion of this subject was presented by Hugh Brown of Vandalia, Mo. He introduces the subject of mechanical aeration. This may be accomplished by the Haworth paddle aerator, the Hartley paddle, the Link Belt and the Simplex aerator. The latter is used to the greatest extent, especially in England.

The new plant at Vandalia uses the Simplex aerator. The plant is built for the capacity of 160,000 gallons per day. It consists of a screen chamber, preliminary settling tank, two Simplex aerators, Dorr clarifier, two sand beds 25 by 50 each, one digester and a pump house with two Fairbanks–Morse pumps. The old plant was a kitchen-type septic tank. This is now used as the digester. The power cost is $64.52 per month

which represents fixed charges at 9 per cent on the investment of $8607. A sprinkling filter plant would have cost at least $10,000 more.

The Requirements for Satisfactory Results from Sewage Treatment Plants. By H. M. BOSCH.—There are two main prerequisites for the satisfactory operation of a sewage treatment plant; namely, a well-designed plant and efficient control. A poorly designed plant with good operation often produces good results but a well-designed plant with poor operation is seldom satisfactory.